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NONLINEAR AEROSOL VAPORIZATION AND BREAKDOWN EFFECTS MODULE NOVAE (UPGRADES SINCE 1984)

April 1991

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ABSTRACT

The nonlinear aerosol vaporization and breakdown effects (NOVAE) high-energy laser propagation model has had a number of improvements added to it since 1984. Many of these improvements address aspects of vertical or slant path propagation of concern to operators of existing or anticipated laser systems. These upgrades include calculation of stimulated Raman scattering and vertical profiling of turbulence and wind. A wide range of aerosol calculations and rectangular laser apertures are also documented. This document also describes operation of the current NOVAE model.

ACKNOWLEDGMENT

The authors would like to acknowledge the efforts of a number of other people in the actual work of improving the NOVAE model. These people arc Sean O'Brien, William Hayden, Yugal Behl, Brian Matise, and Beth Schulze. Most of this work was done on contract for the U.S. Army Atmospheric Sciences Laboratory by OptiMetrics, Inc. under contract DAAD07-84-C-0008.

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1. INTRODUCTION

The Elcctro-Optical Systems Atmospheric Effects Library (**EOSAEL** 87) is a collection of computer codes that address the phenomena associated with electro-magnetic propagation through the atmosphere and the effects that natural and battlefield aerosols can induce. **EOSAEL 87** is well described by the first volume of the **EOSAEL 87** documentation.[1] **NOVAE** is an empirical program, based on scaling laws, that deals with the propagation of high-energy lasers. **NOVAE** was developed from phase propagation models and data to provide fast calculations of propagation effects on high-energy laser propagation. More detailed information may be found in volume 22 of the **EOSAEL** 84 manuals on the air breakdown and thermal blooming aspects of the **NOVAE** code.[2] The phase integral or scaling law approach is also briefly discussed in the earlier documentation. Information calculated by **NOVAE** include laser beam spot size and energy on target, based on input laser parameters, path length, and atmospheric conditions.

A number of upgrades have been implemented[3, 4] in the **NOVAE** code since the publication of volume 22 of the **EOSAEL 84** manuals.[2] This document is a brief discussion of these upgrades, their motivation, and implementation in the **NOVAE** code. It is intended to be used in conjunction with the **EOSAEL 84** manual as a user's guide for the **NOVAE** code in **EOSAEL** 87 library.

The basic motivation behind profiling and stimulated Raman scattering (SRS) options is to more realistically portray high-energy laser propagation for such systems as the High-Energy Laser System Test Facility (IIELSTF) deuterium flouride (DF) laser or the ground-based free electron laser (GBFEL). These systems are very expensive to operate, and system modeling can provide useful information about potential problems with nonlinear effects such as thermal blooming, breakdown, and SRS. The original **NOVAE** code uses vertical scaling of wind, extinction, absorption, and turbulence to simulate atmospheric conditions because propagation along horizontal paths and slant paths with limited vertical extent was originally of interest. Recently, vertical and longer slant paths have become crucial, and more accurate characterization of the vertical profiles is important. This document discusses the use of data for wind, extinction, absorption, and turbulence in **NOVAE.**

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[1] R. C. Shirkey, L. D. Duncan, and F. E. Niles, **1987**, ***EOSAEL 87, Volume I, Executive Summary,*** ASL-TR-0221-1, U. S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

[2] Frederick G. Gebhardt and M. B. Richardson, **1984**, ***EOSAEL 84 Nonlinear Aerosol Vaporization and Breakdown Effects Module-NOVAE,*** ASL-TR-0160-22, U. S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

[3] S. G. O'Brien, **1986**, ***Enhancements of ihe EOSAEL 84 NOVAE Model,*** Proceedings of the Seventh EOSAEL/TWI Conference, U. S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

[4] Patti Gillespie and William Hayden, ***1987, Two Enhancements lo the 87 EOSAEL NOVAE Model,*** Proceedings of tlie Eighth EOSAEL/TWI Conference, U. S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

The **AGAUS** option allows the user a wider variety of smoke lypcs in **NOVAE** calculations where smoke or dust is prominent. The original **NOVAE** used one of three input files of Mie efficiency factors to describe the properties of the smoke in the model or used approximate Mie efficiency factors contained within the model to describe smoke properties.

The rectangular aperture option is included in the **NOVAE** code as a result of a special request of a user. Previously, **NOVAE** contained four aperture types: uniform circular; uniform circular – 10 percent centrally obscured; infinite Gaussian (continuous wave (CW) only); and truncated Gaussian. The recent upgrade of the aperture selection includes a rectangular and a fractionally obscured aperture.

Additionally, some corrections and amplifications to the original text are included in this document to assist the user in using the **NOVAE** model.

2. BACKGROUND

2.1 Absorption and Extinction Coefficient Profiling

The absorption coefficient profiling upgrade includes two additional methods for expressing the molecular absorption with height above ground. The original **NOVAE** model uses simple exponential scaling with height above ground. One of these new methods uses profiles of molecular absorption that can be derived from data or model. The input data file includes height above ground and corresponding molecular absorption. The other option uses the concept of exponential scaling, and coefficients for each month of the year, based on measured data, are provided for the exponential scaling.

These options were developed for the **NOVAE** model based on requirements for high-energy laser testing at White Sands Missile Range (WSMR), New Mexico.[5, 6] Thus all data shown here are specific to WSMR. Most of the effort in this option was directed towards two wavelength regions as well, the near- (1 μm) and mid- (3.8 μm) infrared. Once again this is because this work was done primarily in support of the high-energy laser testing program conducted at WSMR.

The *High-Energy Laser Handbook*[7] was developed for the purpose of support in the high-energy laser test program. Most of the molecular concentrations used in the development of the molecular absorption coefficient profiles come from the *High-Energy Laser Handbook*.[7] The fast atmospheric scattering code (FASCODE) high-resolution transmission model[5, 6]

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[5]S. G. O'Brien, W. D. Hayden, and B. A. Schulae, 1987, Vertical Profiles *of* DF Laser *Line Attenuation* at the High Energy Laser Facility, OMI-226 Contractor Report, prepared under contract DAAD07-84-C-0008, OptiMetrics, Inc., Las Cruces, NM.

[6]S. G. O'Brien, Beth Schulze, and William D. Hayden, 1988, *Vertical* Profiles *of Short Wavelength Attenuation at* White Sands Missile Range, OMI-271 Contractor Report, prepared under contract DAAD07-84-C-0008, OptiMetrics, Inc., Las Cruces, NM.

[7]John R. Hummel (editor), 1984, *High Energy* Laser Propagation *Handbook, vol. II,* HEL *System* Test *Facility Atmospheric Characterization*, ASL-TR-0148, U. S. Army Atmospheric Sciences Lahoratory, White Sands Missile Range, NM.

was used along with the molecular concentrations7 to produce the molecular absorption coefficients. Six molecular constituents: H_2O, CO_2, O_3, N_2O, O_2, and CH_4 had site specific concentrations assigned to them for use in the FASCODE calculations. As mentioned previously, data used in these calculations is specific for each month. Where molecular concentration models are used in these calculations, seasonal averages are sometimes used.

In the near-infrared calculations, water vapor contributes the largest amount of absorption, mainly in the form of the water vapor continuum. This is fortunate since the accuracy of the HITRAN database supporting the FASCODE calculations is known to be questionable in the near infrared, but the water vapor continuum model is reasonable.[*, 8, 9] Water, methane, and carbon dioxide are important in the mid-infrared calculations. This wavelength region has extensive experimental data to validate the HITRAN database, and these calculations are not in question.

Vertical profiles at 1-km intervals for WSMR were produced for both the 1- and 3.8-μm wavelength regions for use with the **NOVAE** model. An exponential fit to the form

$$\alpha = \exp(c_3x^3 + c_2x^2 + c_1x + c_0) \tag{1}$$

using the profiles developed in the discussion above,[5, 6] resulted in coefficients c_i for each month for the mid-infrared wavelength region. x is the height above ground level (AGL) measured in kilometers. Surface aerosol attenuation coefficients for WSMR at 1.06 μm wavelength were developed from data.6 These attenuation coefficients are seasonal averages. For the fall and winter season the mean aerosol extinction is $1.43 \times 10^{-2}\text{km}^{-1}$ and the absorption is $3.13 \times 10^{-3}\text{km}^{-1}$. For the spring and summer season the mean aerosol extinction is $1.20 \times 10^{-2}\text{km}^{-1}$ and the absorption is $2.20 \times 10^{-3}\text{km}^{-1}$.

The user of the **NOVAE** may supply their own absorption coefficients or their own coefficients, c_i, for whatever wavelength region and geographical area is of interest to them. The coefficients for each month for the 3.8-μm region are shown in table 1. These coefficients are for the first 10 km AGL. Above 10 km the extinction is determined using the standard atmosphere extinction.7 A sample absorption coefficient profile is shown in section 5.3. The

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[7] John R. Hummel (editor), 1984, *High Energy Laser Propagation Handbook, vol. II, HEL System Test Facility Atmospheric Characterization,* ASL-TR-0148, U. S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

"Patti Gillespie, 1987, Internal Memorandum, OptiMetrics, Inc., Las Cruces, NM

[8] Patti S. Gillespie, 1989, *Validation of Aerosol Profile Model Developed for HELSTF*, OMI-TN-347, Contractor Report, OptiMetrics, Inc., Las Cruces, NM.

[9] Joseph Manning, 1088, *Updates to the HITRAN Database in the 1.06 μm Region,* Annual Review of Transmission Models, U. S. Air Force Geophysics Laboratory, Hanscom Air Force Base, MA.

[5] S. G. O'Brien, W. D. Hayden, and B. A. Schulze, 1987, *Vertical Profiles of DF Laser Line Attenuation at the High Energy Laser Facility,* OMI-226 Contractor Report, prepared under contract DAAD07-84-C-0008, OptiMetrics, Inc., Las Cruces, NM.

[6] S. G. O'Brien, Beth Schulze, and William D. Hayden, 1988, *Vertical Profiles of Short Wavelength Attenuation at White Sands Missile Range,* OMI-271 Contractor Report, prepared under contract DAAD07-84-C-0008, OptiMetrics, Inc., Las Cruces, NM.

reader is cautioned that all numerical values shown in this document reflect the use of site specific profiles. Numerical values for other geographical areas will be different.

TABLE 1. FIT COEFFICIENTS FOR THE 3.8-μm REGION. THESE ARE USED TO CALCULATE THE ABSORPTION COEFFICIENTS FOR THE FIRST 10 km AGL FOR EACH MONTH. THESE ARE THE COEFFICIENTS USED IN EQUATION 1.

Month	c_3	c_2	c_1	c_0
January	-1.070×	2.530×10^{-2}	-3.607×10^{-1}	-3.679
February	-1.340×10^{-3}	2.962×10^{-2}	-3.781×10^{-1}	-3.676
March	-1.330×10^{-3}	2.922×10^{-2}	-3.733×10^{-1}	-3.701
April	-4.832×10^{-4}	1.611×10^{-2}	-3.235×10^{-1}	-3.704
May	-2.783×10^{-4}	1.644×10^{-2}	-3.697×10^{-1}	-3.453
June	1.425×10^{-3}	-9.917×10^{-3}	-2.868×10^{-1}	-3.307
July	1.470×10^{-3}	-5.300×10^{-3}	-3.882×10^{-1}	-2.802
August	1.324×10^{-3}	-2.312×10^{-3}	-4.075×10^{-1}	-2.763
September	3.312×10^{-4}	1.315×10^{-2}	-4.470×10^{-1}	-2.931
October	-8.021×10^{-4}	2.919×10^{-2}	-4.666×10^{-1}	-3.224
November	-1.141×10^{-3}	2.839×10^{-2}	-3.934×10^{-1}	-3.572
December	-1.067×10^{-3}	2.555×10^{-2}	-3.683×10^{-1}	-3.640

2.2 AGAUS Option

NOVAE uses Mie efficiency factors to calculate the effects of aerosol on laser beam propagation. These Mie efficiency factors may be either exact or approximate. The exact Mie efficiency factors require an additional input file for NOVAE model calculations. These input' files are specific for the type of aerosol. In order to alleviate the tedium of generating these input files each time a new aerosol type is used in NOVAE, the AGAUS option was implemented in NOVAE.[10] AGAUS is an auxiliary EOSAEL module that is used as a subroutine in NOVAE.[11] Program AGAUS treats electromagnetic scattering and absorption of spherical particles by Mie theory. It allows scattering properties to be calculated for. distributions of particle sizes. The principle quantities calculated by AGAUS are extinction, .absorption, scattering, and backscattering coefficients. It also calculates the angular intensity distribution of scattered radiation when unpolarized radiation is incident upon the particles. AGAUS is considerably stripped down from its original form. The module calculates phase functions

[10] Yugal K. Behl, 1985, *Propagation Modeling* WAO 8503-3, Third Quarterly progress report, 1 April 1985 to 30 June 1985, under contract number DAAD07-84-C-0008, OptiMetrics, Inc., Las Cruces, NM.

[11] August Miller, 1983, *Mie* Code AGAUS 82, ASL-CR-83-0100-3, U. S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

and extinction coefficients for numerous forms of aerosol distributions. The verification of this option in **NOVAE** has not been published in formal or informal report to the extent of our knowledge. Since the exact Mie efficiency factor input files give reasonable results,[2] it must be assumed that the **AGAUS** option will also since it is basically providing the input file of Mie efficiency factors for a specific aerosol.

2.3 Wind Profiling

Wind profiling instead of wind scaling might be chosen in the **NOVAE** model if realistic windspeeds and wind directions with respect to height are desired. Realistic winds do not decrease exponentially with height, in fact, they may increase and decrease with height several times between ground level and space. Under many circumstances realistic windspeeds and wind directions may not be necessary, but if the modeler wishes to make slant path calculations over a path length greater than 1 km, and thermal blooming is of concern, the modeler should input a vertical profile for windspeed and wind direction. Calculations over a horizontal path do not require wind profiling since the windspeed and wind direction at that height above ground are the only values of importance. Thermal blooming is inversely proportional to the windspeed[12] and so if the windspeed decreases significantly at some height above ground level, thermal blooming may become important. Conversely, wind profiling may ventilate the laser beam sufficiently to eliminate the possibility of thermal blooming.

Other laser propagation effects may be induced in part by windspeed and wind direction at a given height above ground.

2.4 C_n^2 Profiling

In the **EOSAEL** 84 **NOVAE** the index of refraction structure constant, C_n^2, is scaled with height through the use of a commonly accepted power law. The index of refraction variation arises from the interaction of mechanical wind turbulence and vertical gradients in the index of refraction caused by changes in temperature and pressure. Optical turbulence can have a significant impact on laser beam propagation. The value of tlie exponent in the power law must be nearly one to make the scaling approximation valid.[13] When an arbitrary vertical profile is used to generate a power law scaling, powers much larger than one can result in

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[2]Frederick G. Gebhardt and M. B. Richardson, 1984, *EOSAEL 84 Nonlinear Aerosol Vaporization and Breakdown Effecis Module-NOVAE*, ASL-TR-0160-22, U. S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

[12]Patti Gillespie, Brian Matise and Dennis Garvey, 1988, *Disiortion Number Profiles as Predictors of Thermal Blooming,* Proceedings of the Ninth EOSAEL/TWI Conference, U. S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

[13]H. Breaux, 1978, *Corrections of Extended Huygens-Fresnel Turbulence Calculations for a General Case of Till-Correcled and Uncorrected Laser Apertures,* Internal Memorandum Report No. 600, U. S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD.

regions where C_n^2 is changing rapidly. The turbulence scaling law is given by,

$$C_n^2(z) = C_n^2(z_o)\left(\frac{z}{z_o}\right)^{-q} \tag{2}$$

where z_o, $C_n^2(z_o)$, and q must be input to the model. The nominal values for these parameters are $z_o = 1$ m, $C_n^2(1 \text{ m}) = 5 \times 10^{-14}$ $\text{m}^{-2/3}$, and q = 1.075. Using reasonable, that, is, positive, values of q in equation (2) results in values of the turbulence structure constant that are decreasing with height.

A comparison of power law scaling of C_n^2 and a smoothed data set of C_n^2 is shown by Gillespie and Hayden.[4] A sample data file is given in the sample input and output section 5.2.

C_n^2 is used in the calculation of the coherence length,

$$r_o = 1.675\left\{k^2 \int C_n^2(z')\left(1 - \frac{z'}{z}\right)^{5/3} dz'\right\}^{-3/5} \tag{3}$$

where k is the wavenumber.2 Note that equation (3) is corrected from what appears in volume 22 of the EOSAEL 84 documentation, but matches expressions found in the original work.[13] The factor of $(1 - z'/z)^{5/3}$ is a geometrical factor[14] that indicates that the effect of turbulence is greater near the laser, rather than near the target or intermediate in the path. From a physical point of view this makes sense because NOVAE model was originally written for horizontal and slant paths near the earth's surface. For these cases, the effect of turbulence is greatest near the laser. Other geometrical factors may be found in the literature that describe the effect of turbulence near the target or intermediate between the target and laser.

The arbitrary profile algorithm was tested against the scaling law algorithm by using the power law to generate a profile of C_n^2 values. Theoretically, such a profile should produce similar laser spot size on the target as the power law. Table 2 shows that for four different paths ranging from vertical to horizontal, with two intermediate slant paths included, the profile algorithm gives nearly the same results as the power law algorithm when the power law is used to generate the profile.

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[4] Patti Gillespie and William Hayden, 1987, *Two Enhancements to the 87* EOSAEL NOVAE *Model,* Proceedings of the Eighth EOSAEL/TWI Conference, U. S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

[2] Frederick G. Gebhardt and M. B. Richardson, 1984, EOSAEL *84 Nonlinear Aerosol Vaporization and Breakdown Effects Module-NO*VAE, ASL-TR-0160-22, U. S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

[13] H. Breaux, 1978, *Corrections of Extended Huygens-Fresnel Turbulence Calculations for a General Case of Till-Corrected and Uncorrected Laser Apertures,* Internal Memorandum Report No. 600, U. S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD.

[14] E. C. Crittenden Jr., A. W. Cooper, E. A. Milne, G. W. Rodeback, S. H. Kalmbach, R. L. Armstead, D. Land, and B. Katz, 1976, *Optical Propagation Through Turbulence in the Marine Boundary Layer,* Proceedings of the Optical-Submillimeter Atmospheric Propagation Conference, Boulder, CO.

The arbitrary profile calculation has been used to calculate laser spot size on target for three profiles for propagation along a slant path. These calculations are shown in table 3. Two of the profiles are experimental data and the third is an empirical model based on data.[15] The laser spot sizes calculated for these three cases seem reasonable. Two of the cases are representative of more turbulent conditions: daytime data and a summer model for C_n^2. These two models give larger spot sizes at range than does the profile of :nighttime data. The same file of nighttime data has been used to calculate spot size at range for a vertical path. The vertical path should include less turbulence than a slant path. Indeed, the slant path spot size at range is larger than the vertical path spot size at range for the nighttime C_n^2 data.

TABLE 2. LASER SPOT SIZE AT RANGE. POWER LAW VERSUS PROFILE ALGORITHMS ARE COMPARED.

	Laser Beam Diameter	
Path	Power Law	Profile
Vertical path 1 km	**0.1464** cm	**0.1464** cm
Near zenith slant path **1.025** km	**0.1499**	**0.1521**
30° slant path 2 km	**0.4299**	**0.4366**
Horizontal path 2 km	**5.999**	**5.999**

TABLE 3. LASER SPOT SIZE AT RANGE FOR ACTUAL MEASURED PROFILES

Path	Profile Type	Beam Radius
30" slant path 2km	Empirical summer model	**2.766** cm
30" slant path 2km	Daytime data	2.179 cm
30° slant path **2km**	Nighttime data	1.187 cm
Vertical path 2 km	Nighttime data	0.838 cm

2.5 Stimulated Raman Scattering

SRS is a second order Raman effect that results from the interaction of intense radiation and the molecules immersed in that radiation. This interaction causes the shifting of the radiation in that field to a different frequency, thus changing the total field intensity. SRS may cause a significant loss of energy to intense laser radiation in the atmosphere. The amount of energy

[15] S. G. O'Brien and Edward J. Burlbaw, 1988, *Interim Results for Vertical Profiles of Optical Turbulence at White Sands Missile Range*, OMI-TN-307, published as a contractor report, OptiMetrics, Inc., Las Cruces, NM.

converted from the original frequency to the Raman frequency exponentially increases with the incident field flux. While the change from one frequency to another may cause a change in atmospheric transmission, the major effect due to SRS is a very large defocussing of the shifted wavelength beam. The beam defocus is so severe that propagation of the beam is essentially terminated.[16]

SRS is of particular interest in relation to high-energy laser radiation propagation. It has been observed experimentally in liquids and gases in the laboratory.[17] Various calculations from theoretical models indicate that SRS could occur in atmospheric nitrogen under certain conditions, namely very high laser power combined with short pulse length. However, experimentally we know that air breakdown and thermal blooming interfere with the occurrence of SRS.[18] Also other nonlinear optical phenomena such as self-focusing or stinnulated Brillouin scattering compete for the available photons, and these other effects may occur instead of SRS.[19]

Yariv derives an expression relating the scattered radiation intensity, $I_s(z)$, to the path length, z, and a gain factor, g_s,[19]

$$I_s(z) = I_s(0)e^{g_s z} \tag{4}$$

where $I_s(0)$ is said to be the spontaneous Raman scattered signal. The gain factor is actually a gain per unit length that is directly proportion to increasing intensity and is also somewhat frequency dependent. We see then that the scattered intensity becomes somewhat larger with increasing distance from the source if the gain has a positive, finite value. The theory of stimulated Raman scattering and the development of expressions for the gain are found in the literature.[16, 19, 20]

From the above expression a rule of thumb to determine the onset of SRS has been developed for the scattered intensity.[16] When the ratio of the scattered radiation intensity at two different path lengths attains a critical value, for example, when $I_s(z)/I_s(0) = \exp(30)$, then significant loss of power due to SRS from the laser beam is said to have taken place. During the calculations **NOVAE** keeps track of the product, $g_s z$, for incremental steps along the propagation path. Thus when the product $g_s z$ reaches 30, a threshold for SRS is passed. We say then that SRS has been initiated in the laser beam. The model employed here is based on this concept.

Additionally, beam divergence occurs with the onset of SRS because the scattered radiation has a random direction of propagation and loses all phase coherence. The beam divergence is a measure of how much radiation is scattered out of the beam.

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[16] D. W. Barrett, R. L. Battistelli, E. D. Kostic, R. D. Quinnel, and M. C. Fowler, 1986, *Short Wavelength* Advanced Technology Modeling, Volume 1 SWATM Analysis System Modcling, United Technologies Research Center, East Hartford, CN.

[17] Fred M. Johnson, 1985, CRC Handbook of Lasers, CRC Press, Boca Raton, FL, pp.526–30.

[18] M. A. Henesian, C. D. Swift, and J. R. Murray, 1985, *Stimulated* Rotational *Raman Scattering* in. Nitrogen. *in* Long *Airpaths*, Optics Letters, **10:** 565–7.

[19] A. Yariv, 1075, *Quantum Electronics*, 2nd edition, John Wiley and Sons, New York.

''Y. R. Shen, 1984, The Principles of Nonlinear Optics, John Wiley and Sons, New York.

Both experimentation and analysis have shown that air breakdown and thermal blooming interfere with the occurrence of SRS.[18] Consequently, for most cases of input power and pulse length in our model, both breakdown and blooming must be artificially suppressed in the calculations for SRS to be initiated. Turbulence and jitter also interfere with the initiation of SRS because they have the effect of beam attenuation. We have conducted a sensitivity study of the SRS model to determine the relative effects of SRS for various input parameters. Any correlation between the laser parameters used in this study and real systems is incidental. This study is simply an exercise of the model.

As an example, for a pulsed laser system having pulses of 1.0×10^6 kJ, a pulse length of 5×10^{-6} s, and a repetition rate of 10 Hz, vibrational SRS is computed to be initiated at 99.7 m along a propagation path that extends vertically from the ground up to 1 km. In this calculation the beam diameter enlarges from about 2.18 m to 304 m within a distance of 0.25 km. For SRS to occur in our calculation, however, the breakdown option is turned off, the attenuation due to extinction is not included in the SRS calculation, the jitter is set to zero, and turbulence is set to a minimal nighttime value.[4]

Rotational SRS is computed to occur at 366.8 m along the same propagation path under the same conditions if we substitute a CW laser source with approximately 500 MW power output. In this case the computed beam diameter enlarges from 1.3 m to 50,000 m within a distance of 0.1 km. If the CW device is changed to 500 kW power output, then SRS does not occur anywhere along the propagation path. If breakdown and blooming calculations are included in the propagation calculations, SRS is not initiated in any of these model calculations. The model makes no attempt to determine which process is initiated first along the beam propagation, but it is apparent that once one of these processes—breakdown, blooming, or SRS—is initiated, then the others will not occur, because too much of the beam energy has been dissipated or diverted.

2.6 Rectangular Aperture

The NOVAE model in its present form treats diffraction, thermal blooming, turbulence, jitter, air breakdown, aerosol vaporization, and SRS effects on the laser spot size on target and the irradiance on target. The effects of turbulence, thermal blooming, jitter, and diffraction are represented as modifications of the spatial distribution of irradiance on target. The total radius of the beam spot size on target is represented as the root sum square of the radii due to each of these effects separately. In the NOVAE model the effects of jitter and turbulence are divided into high frequency and low frequency contributions. Only the high frequency terms effect the effective beam size due to thermal blooming. The low frequency terms are included in the root sum square calculation of the other terms with thermal blooming. This

[18] M. A. Henesian, C. D. Swift, and J. R. Murray, 1985, *Stimulated Rotational Raman Scattering in Nitrogen in Long Airpaths*, Optics Letters, *10:* 565–7.

[4] Patti Gillespie and William Hayden, 1987, *Two Enhancements to the 87 EOSAEL NOVAE Model*, Proceedings of the Eighth EOSAEL/TWI Conference, U. S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

is represented mathematically as

$$r^2 = (r_d^2 + r_{th}^2 + r_{jh}^2)HB + r_{tl}^2 + r_{jl}^2 \tag{5}$$

where r is the total beam radius on target, r_d is the beam radius due to diffraction only, r_{th} and r_{tl} are the beam radii due to high and low frequency turbulence, r_{jh} and r_{jl} are the beam radii due to high and low frequency jitter, and HB is the thermal blooming operator.[21]

The spot size on target is assumed to be symmetric. The thermal bloomirig operator is an additional contribution to the total beam radius that is combined in the root sum square calculation. The thermal blooming operator can also be represented as an additional contribution to the total radius. If we neglect the low frequency terms we can write the total radius, r, as

$$r^2 = r_d^2 + r_{jh}^2 + r_{th}^2 + r_b^2 \tag{6}$$

where r_b is an effective "blooming radius."

Deviations from diffraction limited beam diameters are represented in the **NOVAE** model by the use of beam quality. The beam quality is the ratio of the actual spot size to the diffraction limited spot size. A diffraction limited beam quality is equal to 1. The expression for beam quality is given by

$$A_M = MA_D \tag{7}$$

where A_M is the spot size (area) for a beam quality, M, and A_D is the diffraction limited spot size (area).[21]

The rectangular aperture option integrated into the **NOVAE** model utilizes a diffraction model for beam shapes. Rockower of the Naval Postgraduate School has developed a model for including the effects of diffraction for both rectangular apertures and apertures with arbitrarily large central obscuration.22 This model utilizes an effective beam quality M' that is dependent on the beam perimeter to area ratio. This diffraction model is derived from considerations from imaging theory.

From conservation of energy considerations, Rockower has developed the equivalent encircled energy theorem.[22] Techniques derived from modulation transfer function (MTF) theory were applied to a uniformly illuminated aperture of arbitrary shape, resulting in an asymptotic approximate formula for estimating the fraction of encircled energy, E, within a given radius for large distances z,

$$E(z) = 1 - \frac{\lambda f R}{2\pi^2 z} \tag{8}$$

where λ is the wavelength of the laser, R is the aperture perimeter to area ratio, f is the effective focal length.

The principal feature of this result is that, asymptotically, the encircled energy is dependent on the aperture perimeter to area ratio, R, only. For this to be true, the laser beam must

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''B. K. Matise, P. S. Gillespie, and B. A. Schulze, 1989, *Modeling the Propagation of Lasers with Rectangular Apertures*, OMI-TN-342, Contractor Report for DAAD07-84-C-0008, OptiMetrics, Inc., Las Cruces, NM.

''Edward B. Rockower, 1985, Laser *Propagation Code Study, Appendix K*, Naval Postgraduate School, Monterey, CA.

propagate in a linear medium, with no effects of atmospheric fluctuations, wind, temperature, and pressure and the laser aperture must be uniformly illuminated. Rockower concludes that a beam from an aperture with double the value of R will spread twice as much from diffraction.

Phase front distortions resulting in degraded beam quality are a well-known consequence of imperfections of laser wavefront quality at the point where the beam leaves the aperture. These phase front distortions may result from inhomogeneities in the lasing medium, mirror, lens imperfections, or other limitations to the laser system. Here this property is represented by the beam quality, M. The value of beam quality is given in terms of "times diffraction limited" where the value of 1 indicates a diffraction limited rate of beam divergence proportional to λ/D, where D is the beam diameter.

The product of the beam quality and the aperture perimeter to area ratio represents a possible method for modeling the beam spread. This product is preserved due to the conservation of energy,

$$M\,R = M'R'. \tag{9}$$

Equation (9) implies that the effective beam quality may be found from $M' = M(R/R')$.

Rockower's model uses a uniform circular aperture to model a rectangular aperture or circular aperture with arbitrary central obscuration if the lasers are of equivalent power and intensity. Another requirement of this model is that the cross-sectional areas of the two beams under consideration (circular and rectangular or circular and circular with obscuration) be equal.

If the radius of the circular aperture is given by

$$r = \frac{A}{\pi} \tag{10}$$

and the areas of the circular and rectangular apertures are equal, and we define an aspect ratio, F, of length, y, to width, x, dimension, or length to width ratio, then the effective beam quality for a rectangular aperture laser is[21]

$$M' = \frac{M(F+1)}{\sqrt{\pi F}}\ . \tag{11}$$

Similarly for a circular aperture with arbitrary central obscuration given by F, a fractional obscuration between 0 and 1, the effective beam quality is[21]

$$M' = \frac{M(1+\sqrt{F})}{\sqrt{1-F}} \tag{12}$$

and

$$D' = \frac{D}{\sqrt{1-F}} \tag{13}$$

where D' is the new beam diameter.

[21]B. K. Matise, P. S. Gillespie, and B. A. Schulze, 1989, *Modeling the Propagation of Lasers with Rectangular Apertures*, OMI-TN-342, Contractor Report for DAAD07-84-C-0008, OptiMetrics, Inc., Las Cruces, NM.

Note that the meaning of F is different for the rectangular aperture and the arbitrary central obscuration. The new beam diameter for the arbitrary central obscuration is found by setting the old and new beam areas equal and defining the fractional obscuration F as the ratio of the area of the central obscuration, A_1, to the area of the new beam A'. The expression for the resulting beam quality is found from solving the expression $MR = M'R'$ for the value of ***hil'***.

The relationships between beam diameters and MR products that we have discussed hold only for non–thermal blooming cases. Rockower uses BRLPRO (an early version of NOVAE) code runs to show that the expected asymptotic behavior between circular and fractionally obscured circular apertures does not occur for cases where thermal blooming is important. For low energy cases, this model should be sufficient for rectangular or fractional obscured apertures. The reader is referred to the work of Rockower for further details.[22]

3. ADDITIONS TO THE NOVAE INPUTS

3.1 Absorption and Extinction Coefficient Profiling

To implement the three different absorption coefficient options, a new record is needed in the NOVAE input deck. This record starts with the identifier APRO. There are five entries on this record. The first entry is the IAEPRO entry that indicates which absorption coefficient option is to be used.

If the value of IAEPRO is 0, the original exponential vertical scaling is used. If IAEPRO is 1, the vertical profile model given by equation (1) is used. If this option is used, the other four entries on this record must be specified, as they are the four coefficients in the model, c_0, c_1, c_2, and c_3. The entries for c_0, c_1, c_2, and c_3 do not need to bc specified unless IAEPRO is 1.

If the value of IAEPRO is 2, an arbitrary vertical profile of absorption coefficients must exist in the file named ALPHA.PRO for the **NOVAE** model to read in. The left column of the ALPHA.PRO file **is** the height above ground in kilometers. The corresponding absorption coefficients are expected in the second column from the left. The absorption coefficients arc in units of kilometers^{-1}. An example of such a data file is shown in section **5.3.** The height above ground and extinction are read using "free format." An example of at least one of these upgrades is included in the sample input and output.

3.2 AGAUS Option

The switch for determining the type of Mic efficiency factors used in NOVAE is the parameter DATAP on the AVBI record. If DATAP is 1, the files of exact Mie efficiency factors are needed. These files have names beginning with the letters QTO. These files are named **QTOGDO.MIE**,

[22] Edward B. Rockower, 1985, *Laser Propagation Code Study, Appendix K*, Naval Postgraduate School, Monterey, **CA.**

QTOGDT.MIE, and QTOGDF.MIE; they are the Mie efficiency factors for water, Wp/Rp smoke, and fog oil, respectively. These are the only aerosols that have precalculated, exact Mie efficiency factors. If the use of another aerosol is desired, the aerosol type, IAERO, must be greater than 0.0, but no larger than 3.0; and the parameter DATAP must be equal to 3.0. If DATAP is 2.0, approximate Mie expressions are used. If DATAP is 3.0, the AGAUS option is invoked. To use the AGAUS option the parameter IAER on the AVB1 record must be greater than 0. This determines the type if aerosol. A value of 1.0 indicates water, 2.0 indicates Wp/Rp smoke, and 3.0 indicates fog oil smoke. Values of -1.0 mean dust/nonvaporizing materials and 0.0 means no aerosols. The NOVAE scenario should also include a cloud (determined by the AVB2 record) containing the parameters for range to the cloud, RNGA, in kilometers; cloud length, LA, in meters; and fractional cloud transmittance, TA.

One must also have the files AG.DAT and AG.OUT residing in the directory where the model runs are being made. AG.DAT is the AGAUS input file. AGAUS record types 1, 2, 4, and 5 are needed.

Record 1 is a title record only. Record 2 inputs the parameters NWAVE (1.0), BIIDSTP (3.0), IW (1.0), IDELT (0.0), NANG (1.0), IANG (1.0), NBINS (0.0), IEO (0.0), NEOU (0.0), NUNIT (0.0), and MQRIE (2345.0). Nominal values for these parameters are given in the parentheses. NWAVE is the number of wavelengths considered. NIDSTP is the number of size distribution types to be combined at each wavelength. The maximum value of NIDSTP is 5.0. IW determines whether the aerosols are to be considered as water where a value of 0.0 indicates water. IW input is overridden by the passing of the parameter IAER and is set equal to IAER - 1.0. IDELT is used to signal the presence of record type 3a where 0.0 means not present and 1.0 means that it is present. NANG specifies the number of angles at which the phase function is calculated. If it is 0.0 or 1.0, then the phase functions are of no particular interest. IANG equal to 1.0 means that the phase function calculation uses equally spaced angles between 0" and 180°. If NBINS equals 3.0, then there must be no records of type 3c in the input. IEO, NEOU, and NUNIT are logical unit numbers of output. Definitions of these parameters are found in the AGAUS documentation.

Record type 4 reads in IDSTP, Q1Q2, Q3,Q4, Q5,and Q6. A mode 7 calculation needs an IDSTP, Q1, Q2, and Q3. IDSTP denotes the mode 7 calculation. Q1 and Q2 are the minimum and maximum particle radii to consider. Q3 is the increment in particle radius for each calculation.

Record type 5 inputs WAVE, EMA, CAYA, RHOA, CONC, RELHUM, TEMP, and EMUA. WAVE is overridden by the transfer of the wavelength from the main NOVAE routine. EMA and CAYA are overridden if the temperature is nonzero when water is the aerosol under consideration, or these values are passed through the call from the main routine if the aerosol is not water. These two parameters are the real and imaginary indices of refraction. RHOA and CONC are not used. If RELHUM and EMUA are zero, the Hanel growth factor is ignored. If they are not zero, the aerosol will grow larger as the relative humidity increases.

AG.OUT is principally the Mie efficiency factor table. This file is the only indication that AGAUS is used in the NOVAE calculation except that the NOVAE output contains a single reference detailing how the Mie efficiency factors are obtained. This reference is a single line stating whether the approximate Mie expressions were used, exact Mie efficiency factors

were used, or **AGAUS** Mie calculations were used in **NOVAE.**

3.3 Wind Profiling

The original **NOVAE** model contains a wind scaling model that allows the user to input a windspeed at 1 m AGL and scales that windspeed with height above ground with a power law. The exponent of this power law is also input in the original **NOVAE** model. Volume 22 of the EOSAEL 84 documentation recommends a value of 0.142 for the exponent. These two inputs for wind scaling are HWINDO and WNDPOW and they appear on the **ATM1** record. In addition, if slewing of the laser beam is used a wind direction may be specified in the wind scaling. This is the parameter ANGWND also on the **ATM1** record.

To implement the wind profiling option one must include an input record named **WPRO** with the single entry being 1.0 for turning on the wind profiling option and 0.0 for turning off the wind profiling option. If the WPRO record is not present in the input deck, wind scaling is used in the **NOVAE** model. A wind profile that covers the propagation :range of interest must be provided for use with **NOVAE** if the wind profiling option is selected.

The wind profile is set up in a three column configuration with the height above ground in kilometers in the left hand column and the corresponding windspeeds and wind directions in the second and third columns. Windspeed is given in meters per second and wind direction in degrees measured clockwise from north. The wind data is entered in an unformatted read so no special attention need be paid to the spacing of the data. If a height above ground for a given propagation step in **NOVAE** is not represented in the wind profile, a linear interpolation is performed between the pertinent heights for windspeed and wind direction.

Wind profiling may be used with or without the slewing of the laser beam. A sample wind profile is given in section 5.1.

3.4 C_n^2 Profiling

C_n^2 scaling is implemented in **NOVAE** using the CNSQO and CNSQPW parameters on the **ATM1** record. Tlicse are the value of the optical turbulence at 1 m AGL and the power with which to scale the turbulence.

The actual implementation of the vertical profiling of C_n^2 is not as simple as it appears because of subtleties in the approximations used. A new subroutine to numerically integrate the coherence length is called **RCIPRO**. Only one parameter has been added to the record order independent input of **NOVAE** to implement this option. The new parameter, **CN2FLAG**, has been added as the last entry on the **ATM1** record. This parameter is a flag that turns on (1.0) or off (0.0) the vertical profiling option for C_n^2. If the **CN2FLAG** parameter is 1.0, the inputs for the power law scaling are ignored.

Tlic subroutine RCIPRO reads a "free format" input file named CN2.**PRO** as input data for C_n^2. This file has two columns, the left column containing the heights above ground level

in kilometers and the right column containing the corresponding C_n^2 values. The vertical spacing of the C_n^2 profiles need not necessarily be equal and there is a limit; of 500 profile entries.

At each propagation step in the phase integral in NOVAE, RCIPRO determines the limits of integration for the coherence length integral for that step, determines the value of C_n^2 by logarithmic interpolation, inserts the value into the integral representation of the coherence length, and performs a Romberg integration on the coherence length integral. Since a propagation path in NOVAE is divided into at least 20 steps, RCIPRO evaluates the coherence length integral for each of these intervals to give a resultant coherence length value at each step. This can be contrasted to using the power law expression for C_n^2 in the coherence length calculation where an approximation is made for the coherence length at each propagation step in the NOVAE calculation. The price of using an arbitrary vertical profile instead of the power law for C_n^2 is an additional factor of 10 in the computation time. A comparison of power law scaling of C_n^2 and a smoothed data set of C_n^2 shows that there are distinct differences between the two on occasion.[4] These differences can result in significantly different spot sizes on target. Turbulence data can show both increases and decrease:; in value with height over short intervals in height, though with a generally decreasing trend over longer intervals. The scaling law shows only the decreasing trend. A sample data file is given in the sample profile chapter. The arbitrary profile option for optical turbulence may use actual data, smoothed data, or values of turbulence at given heights above ground for another turbulence model.

3.5 Stimulated Raman Scattering

The algorithm used in the NOVAE model to calculate the SRS effect has been adapted from the U.S. Air Force Short Wavelength Advanced Technology Modeling Propagation Codes.[16] The basic theoretical concept utilized in the model is if the integrated gain at any height AGL exceeds 30, then SRS is initiated and beam propagation is terminated.

Specifically, the SRS model checks to determine if rotational or vibrational SRS is to be considered, and it uses that information to calculate the gain at that height AGL. Expressions for the gain have been developed[16] that depend on the height AGL and whether the SRS is rotational or vibrational. Currently, it is thought that rotational SRS ($J = 8$ or 10) is the most likely of the SRS phenomena to occur.[18] After the gain at a given height is calculated, the integrated gain over height is calculated and compared to 30. If the integrated gain is less

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[4] Patti Gillespie and William Hayden, 1987, Two Enhancements to the *87 EOSAEL* NOVAE: Model, Proceedings of the Eighth EOSAEL/TWI Conference, U. S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

[16] D. W. Barrett, R. L. Battistelli, E. D. Kostic, R. D. Quinnel, and M. C. Fowler, 1986, *Short Wavelength* Advanced *Technology* Modeling, Volume 1 SWATM Analysis System Modeling, United Technologies Research Center, East Hartford, CN.

[18] M. A. Henesian, C. D. Swift, and J. R. Murray, 1985, Stimulated Rotational *Raman Scattering in* Nitrogen in Long *Airpaths*, Optics Letters, 10: 565–7.

than 30, the module returns to the main program and computation is continued on the next step. If the integrated gain is greater than **30,** then a message is printed to the output file that SRS has occurred at that height and no further beam propagation should be considered. Then the defocussing effect of SRS is calculated and a new beam diameter is determined based on the amount of defocussing due to SRS. This new beam diameter is passed back to the main NOVAE routine and a new power per unit area, based on the divergence due to SRS, is calculated and used throughout the remainder of the NOVAE model. This process is repeated at each propagation step in the calculation.

The beam defocusing calculation is the most approximate part of the algorithm, and perhaps the best way to use the SRS option of NOVAE is to simply note the distance along the range where SRS occurs and to consider that the beam propagation ends there. We do not wish to imply that the defocusing calculation is wrong, but rather that the defocusing is so great that the concept of beam propagation beyond where SRS initiates has little meaning.

For SRS calculation, a new record has been added to the record order independent input. This record is named **ATM3** and contains the following input parameters:

- IRAM, turns SRS on (1.0) or off (0.0)

- SRSTYPE, determines whether the SRS is rotational or vibrational. SRSTYPE is 1.0 for vibrational SRS and 2.0 for rotational SRS.

- SRSLINE, determines which J-value is being considered for the rotational SRS calculation. This parameter is specified only if the rotational SRS calculation is chosen. It may be set to 8.0 or 10.0 to define the J-value of the transition.

- **IRAME**, acts as the on (1.0) or off (0.0) switch to include the attenuation due to scattering, absorption, and breakdown in the SRS gain calculation.

A sample input and resulting output are included at the end of this document displaying typical results using the SRS option.

3.6 Rectangular Aperture

The rectangular or fractionally obscured aperture options are implemented by changes on two input records, LAS1 and **LAS2.** The LAS1 record now contains the parameters DIAM, POWER, POWMAX, ENGPUL, ENGMAX, and FOBS. FOBS is one of the new parameters for this option, and the other parameters are discussed in volume 22 of the EOSAEL 84 documentation.[2] FOBS is the fractional obscuration of a circular aperture. This parameter should be set equal to 0.0 or omitted when not in use. When the fractionally obscured aperture is used, the value of FOBS is between 0.0 and 1.0.

[2] Frederick G. Gebhardt and M. B. Richardson, 1984, EOSAEL 84 ***Nonlinear Aerosol Vaporization and Breakdown Effect Module-NOVAE,*** ASL-TR-0160-22, U.S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

The **LAS2** record contains the parameters **PRF, TO, TIMSDL, THJH, THJL, ASPECT,** and **XDIM. ASPECT** and **XDIM** are the new parameters on this record. **ASPECT** is simply the aspect ratio or the ratio of the y-dimension to the x-dimension of the rectangular aperture. **XDIM** is the x-dimension of the rectangular aperture in meters.

To invoke the rectangular aperture option, the input parameter **IDBM** on record **CTRL** is set equal to 5.0. When **IDBM** equals 5.0 the values of **ASPECT** and **XDIM** must be set to nonzero values also. For example, when **IDBM** = 5.0, and **ASPECT** = 2.0 and **XDIM** = 0.5, we have specified a rectangular aperture of dimensions 0.5 by 1.0 m.

To invoke the fractionally obscured circular aperture, **IDBM** is set equal to 3.0 (circular aperture) and **FOBS** is set to some value between 0.0 and 1.0. For example, if **IDBM** = 3.0, and **FOBS** = 0.2, we have specified a 20 percent centrally obscured circular aperture. The diameter of the aperture that is input to NOVAE through the parameter **DIAM,** is the actual diameter of the fractionally obscured aperture not the diameter of an unobscured aperture with the same transmission area. The model calculates the equivalent diameter of the circular aperture used to represent the fractionally obscured aperture.

The fractionally obscured aperture algorithm has been tested in the following manner. The fractional obscuration was set equal to 10 percent and calculations were made in the NOVAE model. The NOVAE model already contains an algorithm for a circular aperture with 10 percent central obscuration. This option was used and comparisons were made between the two model runs. The agreement between the beam radii and intensities was within a factor of 2. and is better for the diffraction limited case and the turbulence-iittcr case than For the thermal blooming case. Use of the rectangular and fractionally obscured models should be limited to non–thermal blooming cases.

One of the reasons that these aperture options do not extend to thermal blooming cases is that thermal blooming affects the output of a laser with an aperture of dimensions 10 by 15 cm differently than one of dimensions 15 by 10 cm. Our model for rectangular apertures treats an aperture of dimensions 10 by 15 cm the same as one of dimensions 15 by 10 cm. Sample cases of rectangular or fractionally obscured apertures are shown in the sample output chapter in this document.

4. CAVEATS

In the course of upgrading the NOVAE code a number of peculiarities to the NOVAE model were discovered and arc reported here.

The vertical scaling of the optical turbulence parameter with the power law is intended for horizontal or small elevation angle slant path scenarios. This is due to the approximation used in the integration of the coherence length, r_o. The exponent of the power law should be between the values of 0.7 and 1.3. Therefore, if the user intends to model a vertical path scenario, a vertical profile of optical turbulence should be used in the calculation of the coherence length.

The NOVAE module appears to allow the capability of looking at a point past the focal length of the laser beam, but in fact, the model does not accurately handle this situation. Therefore, the value of the input parameter **DRNGFO** must be zero or greater so that the

model calculates spot size and energy on target for a focussed beam at or before the focus.

The original NOVAE documentation recommends that the number of points in the phase integral, NPT, be set equal to 20.0. In fact, serious problems with the NOVAE model occur for NPT > 20.0. NOVAE does not always operate error free for NPT < 20.0. No matter what the path length, it seems that NPT is optimally set equal to 20.

The phase integral calculations in NOVAE are calibrated to be accurate for distances under 30 km. Comparisons have been made with the wave optics model SSPRO and spot size and energy on target begin to diverge at 30 km path length. No guidance has been provided in the past on this topic. The maximum distance of 30 km is the result of a brief sensitivity study and should not be construed as conclusive.

Finally, there have been problems with specific cases of breakdown transmittance being greater than 1. This would indicate a larger than 100 percent transmittance of the beam. The source of this problem was not fully identified, but the current version of the code should at least alert the user if this situation should occur. It is believed that this situation occurs when marginal breakdown occurs and there is a logic error in accumulating the air breakdown effect.

5. SAMPLE INPUT AND OUTPUT

The NOVAE input file for the upgrade version of NOVAE that corresponds to table 8 "NOVAE Identifiers and Parameters" in volume 22 of the EOSAEL 84 documentation[2] is given in table 4..

TABLE 4. NOVAE INPUT PARAMETERS

CARD	PARAMETERS					
LAS1	DIAM	POWER	POWMAX	ENGPUL	ENGMAX	FOBS
LAS2	PRF	TO	TIMSDL	THJH	THJL	ASPECT	XDIM
ATM1	WINDO	HWINDO	ANGWND	WNDPOW	CNSQO	CNSQPW	CN2PRO
ATM2	SCRPTS	ABSOR	ABSSCA	HA	HS	HTDEV	HTTAR
ATM3	IRAM	SRSTYPE	SRSLINE	IRAM			
TAR1	RANGE	DRNGFO	RMT	XT	YT		
TAR2	TRAJAN	BEARAN	SLUVEL				
CTRL	RAV	IDCWRP	IDBM	IDSLEW	NPT	IDTLCO	IDRSS
AVB1	IBRK	IAER	IPRTOP	NPA	IRECON	EXEXSC	DATAP
AVB2	RNGA	LA	TA	TATM	PATM	REHL	
AVB3	NR/MEC	NI/MAC	RM/FAH	SIG	TBOIL	ROA	CPA
AVB4	CPV	LHA	EPSA	DCA	RGA	KAIR	MV
APRO	IAEPRO	C0	C1	C2	C3		
WPRO	WINPRO						
GO							
DONE							

The original input parameters are identified and discussed in volume 22 of the EOSAEL 84

[2]Frederick G. Gebhardt and M. B. Richardson, 1984, EOSAEL 84 *Nonlinear Aerosol Vaporization and Breakdown Effects Module-NOVAE*, ASL-TR-0160-22, U. S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

documentation and the new parameters are discussed in this document.

Included here is also a sample **AG.DAT** file used for the NOVAE-AGAUS input:

```
EFFICIENCY TABLE FOR NOVAE: Wp/Rp Smoke AT 3.8 um.
   1    3    5    0   01    1   00    0    0   00 2345
  7       0.01000   00.100      0.01      2.50   0.100E-12
 3.800E+00 1.380E+00 0.047E-00 .2500E+01 1.000E-09 00.00E+00 2.500
  7       0.12000   01.000      0.02      2.50   0.100E-12
 3.800E+00 1.380E+00 0.047E-00 .2500E+01 1.000E-09 00.00E+00 2.500
  7       1.10000   10.100      0.10      2.50   0.100E-12
 3.800E+00 1.380E+00 0.047E-00 .2500E+01 1.000E-09 00.00E+00 2.500
# THE FOLLOWING IS EOSAEL SOURCE CONTROL INFORMATION YOU CAN SAFELY REMOVE IT
# SCCS  @(#) AG.DAT 2.1 02/23/90
```

Here is the sample **AG.OUT** file generated using the previous input:

```
EFFICIENCY TABLE FOR NOVAE: Wp/Rp Smoke AT 3.8 um.
INTEGER CONTROL PARAMETERS:
NWAVE NIDSTP IW IDELT NANG  IANG  NBINS  IEO  NEOU  NUNIT  NQRTE
  1     3    L   0     1     1     0     0     0     0     2345
     CONVERGENCE CRITERION (DELTA) = 1.000E-03
     MAXIMUM MIE SIZE TO BE USED IS   400.00
LOOPING OPTION IY EFFECT FOR  3 AEROSOL COMPONENTS
 MAXIMUM NUMBER OF RADII FOR EACH INTERVAL IS :   513
AEROSOL COMPONENT YO.  1: TABLE GENERATION MODE
RLO =  1.00000E-02.  MI =  1.00000E-01.  DELR =  1.00000E-02
 WAVELENGTH   =    10.6000 MICROMETERS
REAL INDEX   =  .1380E+01  IMAG. INDEX  =  .4000E+00
GROWTH FACT. =   .00E+00   T  (DEG. C)  =  2.50     REL. HUMIDITY    .00
R(MICRONS) DRY  RADIUS   MIE SIZE     Q(EXT)      Q(SCA)      Q(ABS)      Q(RADAR)   RL INX(ADJ)  I  INX(ADJ)
   .01000 1.00000E-02 5.92753E-03 5.15297E-03 3.82996E-10 5.15297E-03 5.74495E-10 1.38000E+00 4 00000E-01
   .02000 2.00000E-02 1.18551E-02 1.03066E-02 6.14532E-09 1.03066E-02 9.19136E-09 1.38000E+00 4.00000E-01
   .03000 3.00000E-02 1.77826E-02 1.54613E-02 3.10784E-08 1.54612E-02 4.65278E-08 1.38000E+00 4.00000E-01
   .04000 4.00000E-02 2.37101E-02 2.06175E-02 9.80273E-08 2.06174E-02 1.47035E-07 1.38000E+00 4.00000E-01
   .05000 5.00000E-02 2.96377E-02 2.57758E-02 2.39473E-07 2.57755E-02 3.58924E-07 1.38000E+00 4.00000E-01
   .06000 6.00000E-02 3.55652E-02 3.09367E-02 4.96663E-07 3.09362E-02 7.44140E-07 1.38000E+00 4.00000E-01
    07000 7.00000E-02 4.14927E-02 3.61008E-02 9.20126E-07 3.60999E-02 1.37834E-06 1.38000E+00 4.00000E-01
    08000 8.00000E-02 4.74203E-02 4.12686E-02 1.56898E-06 4.12670E-02 2.35084E-06 1.38000E+00 4 00000E-01
   .09000 9.00000E-02 5.33478E-02 4.64405E-02 2.51336E-06 4.64380E-02 3.76460E-06 1.38000E+00 4.00000E-01
    10000 1.00000E-01 5.92753E-02 5.16173E-02 3.83060E-06 5.16135E-02 5.73613E-06 1.38000E+00 4.00000E-01
AEROSOL COMPONENT NO.  2: TABLE GENERATION RODE
RLO =  1.20000E-01.  RHI =  1.00000E+00.  DELR =  2.00000E-02
 WAVELENGTH   =    10.6000 MICROMETERS
REAL INDEX   =  .1380E+01  IMAG. INDEX  =  .4000E+00
GROWTH FACT. =   .00E+00   T  (DEG. C)  =  2.50     REL. HUMIDITY    .00
R(MICRONS) DRY  RADIUS   MIE SIZE     Q(EXT)      Q(SCA)      Q(ABS)      Q(RADAR)   RL INX(ADJ)  IM INX(ADJ)
    12000 1.20000E-01 7.11304E-02 6.19871E-02 7.94218E-06 6.19792E-02 1.18862E-05 1.38000E+00 4.00000E-01
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14000	1.40000E-01	8.29855E-02	7.23825E-02	1.47137E-05	7.23677E-02	2.20024E-05	1.38000E+00	4.00000E-01
16000	1.60000E-01	9.48405E-02	8.28074E-02	2.50992E-05	8.27823E-02	3.74987E-05	1.38000E+00	4 00000E-01
18000	1.80000E-01	1.06696E-01	9.32663E-02	4.02002E-05	9.32261E-02	5.99989E-05	1.38000E+00	4 00000E-01
.20000	2.00000E-01	1.18551E-01	1.03763E-01	6.12670E-05	1.03702E-01	9.13326E-05	1.38000E+00	4.00000E-01
.22000	2.20000E-01	1.30406E-01	1.14303E-01	8.96910E-05	1.14213E-01	1.33531E-04	1.38000E+00	4.00000E-01
.24000	2.40000E-01	1.42261E-01	1.24889E-01	1.27011E-04	1.24762E-01	1.88824E-04	1.38000E+00	4.00000E-01
.26000	2.60000E-01	1.54116E-01	1.35527E-01	1.74905E-M	1.35352E-01	2.59631E-04	1.38000E+00	4.00000E-01
.28000	2.80000E-01	1.65971E-01	1.46219E-01	2.35208E-04	1.45984E-01	3.48558E-04	1.38000E+00	4.00000E-01
.30000	3.00000E-01	1.77826E-01	1.56971E-01	3.09873E-04	1.56661E-01	4.58391E-04	1.38000E+00	4.00000E-01
.32000	3.20000E-01	1.89681E-01	1.67787E-01	4.01030E-04	1.67386E-01	5.92085E-04	1.38000E+00	4.00000E-01
.34000	3.40000E-01	2.01536E-01	1.78670E-01	5.10907E-04	1.78159E-01	7.52760E-04	1.38000E+00	4.00000E-01
.36000	3.60000E-01	2.13391E-01	1.89624E-01	6.41879E-04	1.88982E-01	9.43689E-04	1.38000E+00	4.00000E-01
.38000	3.80000E-01	2.25246E-01	2.00654E-01	7.96485E-04	1.99858E-01	1.16829E-03	1.38000E+00	4.00000E-01
.40000	4.00000E-01	2.37101E-01	2.11763E-01	9.77342E-04	2.10786E-01	1.43012E-03	1.38000E+00	4.00000E-01
42000	4.20000E-01	2.48956E-01	2.22956E-01	1.18727E-03	2.21769E-01	1.73284E-03	1.38000E+00	4.00000E-01
.44000	4.40000E-01	2.60811E-01	2.34235E-01	1.42913E-03	2.32806E-01	2.08025E-03	1.38000E+00	4.00000E-01
46000	4.60000E-01	2.72667E-01	2.45605E-01	1.70595E-03	2.43900E-01	2.47622E-03	1.38000E+00	4.00000E-01
.48000	4.80000E-01	2.84522E-01	2.57070E-01	2.02091E-03	2.55049E-01	2.92472E-03	1.38000E+00	4.00000E-01
.50000	5.00000E-01	2.96377E-01	2.68631E-01	2.37717E-03	2.66254E-01	3.42978E-03	1 38000E+00	4.00000E-01
.52000	5.20000E-01	3.08232E-01	2.80293E-01	2.77816E-03	2.77515E-01	3.99548E-03	1.38000E+00	4.00000E-01
.54000	5.40000E-01	3.20087E-01	2.92060E-01	3.2273kE-03	2.88832E-01	4.62595E-03	1.38000E+00	4 00000E-01
.56000	5.60000E-01	3.31942E-01	3.03933E-01	3.72821E-03	3.00204E-01	5.32533E-03	1.38000E+00	4.00000E-01
58000	5.80000E-01	3 43797E-01	3.15915E-01	4 28442E-03	3.11631E-01	6.09774E-03	1.38000E+00	4.00000E-01
.60000	6.00000E-01	3.55652E-01	3.28010E-01	4 899QE-03	3.23110E-01	6.94732E-03	1.38000E+00	4 00000E-01
.62000	6.20000E-01	3.67507E-01	3.40219E-01	5.57778E-03	3.34642E-01	7.87813E-03	1.38000E+00	4 00000E-01
64000	6.40000E-01	3.79362E-01	3.52546E-01	6.32260E-03	3.46224E-01	8.89418E-03	1.38000E+00	4 00000E-01
.66000	6.60000E-01	3.91217E-01	3.64992E-01	7.13759E-03	3.57854E-01	9.99943E-03	1.38000E+00	4.00000E-01
.68000	6.80000E-01	4 03072E-01	3.77558E-01	8.02790E-03	3 69530E-01	1.11977E-M	1.38000E+00	4 00000E-01
70000	7.00000E-01	4.14927E-01	3.90247E-01	8.99632E-03	3.81251E-01	1.24926E-02	1.38000E+00	4 00000E-01
.72000	7 20000E-01	4.26782E-01	4.03060E-01	1.00472E-02	3.93013E-01	1.38878E-02	1.38000E+00	4.00000E-01
.74000	7.40000E-01	4.38637E-01	4.15998E-01	1.11846E-02	4.04814E-01	1.53866E-02	1.38000E+00	4.00000E-01
.76000	7.60000E-01	4.50493E-01	4.29062E-01	1.24124E-02	4.16650E-01	1.69921E-02	1.38000E+00	4 00000E-01
.78000	7.80000E-01	4.62348E-01	4.42253E-01	1.37347E-02	4.28518E-01	1.87074E-02	1.38000E+00	4 MIOWE-01
.80000	8.00000E-01	4.74203E-01	4.55570E-01	1.51553E-02	4.40415E-01	2.05350E-02	1.38000E+00	4.00000E-01
82000	8.20000E-01	4.86058E-01	4.69014E-01	1.66783E-02	4.52336E-01	2.24773E-02	1.38000E+00	4.00000E-01
.84000	8.40000E-01	4.97913E-01	4.82585E-01	1.83074E-02	4.64278E-01	2.45364E-02	1.38000E+00	4.00000E-01
.86000	8.60000E-01	5.09768E-01	4.96282E-01	2.00463E-02	4.76236E-01	2.67142E-02	1.38000E+00	4 00000E-01
.88000	8.80000E-01	5.21623E-01	5.10104E-01	2.18988E-02	4.88205E-01	2.90118E-02	1.38000E+00	4.00000E-01
90000	9.00000E-01	5.33478E-01	5 24050E-01	2.38684E-02	5.00182E-01	3.14304E-02	1.38000E+00	4.00000E-01
.92000	9.20000E-01	5.45333E-01	5.38119E-01	2.59584E-02	5.12161E-01	3.39706E-02	1.38000E+00	4 00000E-01
94000	9.40000E-01	5.57188E-01	5.52308E-01	2.81723E-02	5.24136E-01	3.66323E-02	1.38000E+00	4 00000E-01
.96000	9.60000E-01	5.69043E-01	5.66616E-01	3.05132E-02	5.36103E-01	3.94155E-02	1.38000E+00	4.00000E-01
.98000	9.80000E-01	5.80898E-01	5.81040E-01	3.29839E-M	5.48056E-01	4.23191E-02	1.38000E+00	4.00000E-01
1.00000	1.00000E+00	5.92753E-01	5.95577E-01	3.55872E-02	5.59990E-01	4.53420E-02	1.38000E+00	4.00000E-01

AEROSOL COMPONENT NO. 3: TABLE GENERATION MODE

RLO = 1.10000E+00. RHI = 1 01000E+01. DELR = 1.00000E-01

WAVELENGTH = 10.6000 MICROMETERS

REAL INDEX : .1380E+01 IMAG. INDEX : .4000E+00

GROWTH FACT. : .00E+00 T (DEC. C) : 2.50 REL. HUMIDITY .00

R(MICRONS)	DRY RADIUS	MIE SIZE	Q(EXT)	Q(SCA)	Q(ABS)	Q(RADAR)	RL INX(ADJ)	IM INX(ADJ)
1.10000	1.10000E+00	6.52029E-01	6.69840E-01	5.06748E-02	6.19166E-01	6.21612E-02	1.38000E+00	4.00000E-01
1.20000	1.20000E+00	7.11304E-01	7.46330E-01	6.93546E-02	6.76975E-01	8.14440E-02	1.38000E+00	4.00000E-01
1.30000	1.30000E+00	7.70579E-01	8.24362E-01	9.16685E-02	7.32693E-01	1.02378E-01	1.38000E+00	4.00000E-01
1.40000	1.40000E+00	8.29855E-01	9.03132E-01	1.17450E-01	7.85682E-01	1.23794E-01	1.38000E+00	4.00000E-01
1.50000	1.50000E+00	8.89130E-01	9.81781E-01	1.46323E-01	8.35458E-01	1.44237E-01	1.38000E+00	4.00000E-01
1.60000	1.60000E+00	9.48405E-01	1.05948E+00	1.77731E-01	8.81752E-01	1.62093E-01	1.38000E+00	4.00000E-01
1.70000	1.70000E+00	1.00768E+00	1.13552E+00	2.1099kE-01	9.24523E-01	1.75766E-01	1.38000E+00	4.00000E-01
1.80000	1.80000E+00	1.06696E+00	1.20933E+00	2.45386E-01	9.63944E-01	1.83877E-01	1.38000E+00	4.00000E-01
1.90000	1.90000E+00	1.12623E+00	1.28056E+00	2.80217E-01	1.00034E+00	1.85461E-01	1.38000E+00	4.00000E-01
2.00000	2.00000E+00	1.18551E+00	1.34903E+00	3.14904E-01	1.03413E+00	1.80117E-01	1.38000E+00	4.00000E-01
2.10000	2.10000E+00	1.24478E+00	1.41470E+00	3.49024E-01	1.06568E+00	1.68102E-01	1.38000E+00	4.00000E-01
2.20000	2.20000E+00	1.30406E+00	1.47763E+00	3.82327E-01	1.09531E+00	1.50327E-01	1.38000E+00	4.00000E-01
2.30000	2.30000E+00	1.36333E+00	1.53790E+00	4.14726E-01	1.12318E+00	1.28281E-01	1.38000E+00	4.00000E-01
2.40000	2.40000E+00	1.42261E+00	1.59560E+00	4.46258E-01	1.14934E+00	1.03862E-01	1.38000E+00	4.00000E-01
2.50000	2.50000E+00	1.48188E+00	1.65077E+00	4.77035E-01	1.17374E+00	7.91718E-02	1.38000E+00	4.00000E-01
2.60000	2.60000E+00	1.54116E+00	1.70346E+00	5.07193E-01	1.19627E+00	5.62804E-02	1.38000E+00	4.00000E-01
2.70000	2.70000E+00	1.60043E+00	1.75370E+00	5.36851E-01	1.21686E+00	3.70109E-02	1.38000E+00	4.00000E-01
2.80000	2.80000E+00	1.65971E+00	1.80155E+00	5.66087E-01	1.23546E+00	2.27655E-02	1.38000E+00	4.00000E-01
2.90000	2.90000E+00	1.71898E+00	1.84708E+00	5.94927E-01	1.25215E+00	1.44093E-02	1.38000E+00	4.00000E-01
3.00000	3.00000E+00	1.77826E+00	1.89040E+00	6.23347E-01	1.26705E+00	1.22197E-02	1.38000E+00	4.00000E-01
3.10000	3.10000E+00	1.83754E+00	1.93162E+00	6.51283E-01	1.28034E+00	1.58932E-02	1.38000E+00	4.00000E-01
3.20000	3.20000E+00	1.89681E+00	1.97087E+00	6.78644E-01	1.29223E+00	2.46044E-02	1.38000E+00	4.00000E-01
3.30000	3.30000E+00	1.95609E+00	2.00823E+00	7.05322E-01	1.30290E+00	3.71062E-02	1.38000E+00	4.00000E-01
3.40000	3.40000E+00	2.01536E+00	2.04375E+00	7.31207E-01	1.31254E+00	5.18652E-02	1.38000E+00	4.00000E-01
3.50000	3.50000E+00	2.07464E+00	2.07746E+00	7.56196E-01	1.32126E+00	6.72200E-02	1.38000E+00	4.00000E-01
3.60000	3.60000E+00	2.13391E+00	2.10935E+00	7.80200E-01	1.32915E+00	8.15503E-02	1.38000E+00	4.00000E-01
3.70000	3.70000E+00	2.19319E+00	2.13940E+00	8.03148E-01	1.33625E+00	9.34382E-02	1.38000E+00	4.00000E-01
3.80000	3.80000E+00	2.25246E+00	2.16760E+00	8.24995E-01	1.34260E+00	1.01801E-01	1.38000E+00	4.00000E-01
3.90000	3.90000E+00	2.31174E+00	2.19395E+00	8.45717E-01	1.34823E+00	1.05980E-01	1.38000E+00	4.00000E-01
4.00000	4.00000E+00	2.37101E+00	2.21849E+00	8.65318E-01	1.35317E+00	1.05782E-01	1.38000E+00	4.00000E-01
4.10000	4.10000E+00	2.43029E+00	2.24130E+00	8.83819E-01	1.35748E+00	1.01455E-01	1.38000E+00	4.00000E-01
4.20000	4.20000E+00	2.48956E+00	2.26249E+00	9.01265E-01	1.36123E+00	9.36349E-02	1.38000E+00	4.00000E-01
4.30000	4.30000E+00	2.54884E+00	2.28222E+00	9.17711E-01	1.36451E+00	8.32458E-02	1.38000E+00	4.00000E-01
4.40000	4.40000E+00	2.60811E+00	2.30065E+00	9.33227E-01	1.36742E+00	7.13958E-02	1.38000E+00	4.00000E-01
4.50000	4.50000E+00	2.66739E+00	2.31791E+00	9.47885E-01	1.37003E+00	5.92594E-02	1.38000E+00	4.00000E-01
4.60000	4.60000E+00	2.72667E+00	2.33415E+00	9.61760E-01	1.37239E+00	4.79676E-02	1.38000E+00	4.00000E-01
4.70000	4.70000E+00	2.78594E+00	2.34944E+00	9.74915E-01	1.37452E+00	33.5079E-02	1.38000E+00	4.00000E-01
4.80000	4.80000E+00	2.84522E+00	2.36383E+00	9.874ME-01	1.37643E+00	3.16421E-02	1.38000E+00	4.00000E-01
4.90000	4.90000E+00	2.90449E+00	2.37733E+00	9.99267E-01	1.37806E+00	2.78456E-02	1.38000E+00	4.00000E-01
5.00000	5.00000E+00	2.96377E+00	2.38991E+00	1.01053E+00	1.37930E+00	2.72763E-02	1.38000E+00	4.00000E-01
5.10000	5.10000E+00	3.02304E+00	2.40155E+00	1.02119E+00	1.38036E+00	2.97755E-02	1.38000E+00	4.00000E-01
5.20000	5.20000E+00	3.08232E+00	2.41220E+00	1.03125E+00	1.38095E+00	3.48998E-02	1.38000E+00	4.00000E-01
5.30000	5.30000E+00	3.14159E+00	2.42185E+00	1.04071E+00	1.38115E+00	4.19811E-02	1.38000E+00	4.00000E-01
5.40000	5.40000E+00	3.20087E+00	2.43052E+00	1.04955E+00	1.38097E+00	5.02044E-02	1.38000E+00	4.00000E-01

5.50000	5.50000E+00	3.26014E+00	2.43825E+00	1.05778E+00	1.38048E+00	5.86954E-02	1.38000E+00	4.00000E-01
5.60000	5.60000E+00	3.31942E+00	2.44513E+00	1.06540E+00	1.37972E+00	6.66059E-02	1.38000E+00	4.00000E-01
5.70000	5.70000E+00	3.37869E+00	2.45123E+00	1.07244E+00	1.37879E+00	7.31903E-02	1.38000E+00	4.00000E-01
5.80000	5.80000E+00	3.43797E+00	2.45669E+00	1.07892E+00	1.37776E+00	7.78666E-02	1.38000E+00	4.00000E-01
5.90000	5.90000E+00	3.49724E+00	2.46158E+00	1.08489E+00	1.37669E+00	8.02600E-02	1.38000E+00	4.00000E-01
6.00000	6.00000E+00	3.55652E+00	2.46602E+00	1.09040E+00	1.37562E+00	8.02267E-02	1.38000E+00	4.00000E-01

VAVELEWCTH = 10.6000 MICROMETERS

REAL INDEX = .1380E+01 IMAG. INDEX = .4000E+00

GROWTH FACT. = .25E+01 T (DEG. C) = .00 REL. HUWIDIN .00

YAVELENGTH = 2.5000 MICROMETERS

REAL INDEX = .0000E+00 IMAG. INDEX =

R(MICRONS)	DRY RADIUS	MIE SIZE	Q(EXT)	Q(SCA)	Q(ABS)	Q(RADAR)	RL INX(ADJ)	IM INX(ADJ)
6.10000	6.10000E+00	3.61580E+00	2.47006E+00	1.09549E+00	1.37456E+00	7.78580E-02	1.38000E+00	4.00000E-01
6.20000	6.20000E+00	3.67507E+00	2.47371E+00	1.10020E+00	1.37350E+00	7.34628E-02	1.38000E+00	4.00000E-01
6.30000	6.30000E+00	3.73435E+00	2.47701E+00	1.10459E+00	1.37242E+00	6.75325E-02	1.38000E+00	4.00000E-01
6.40000	6.40000E+00	3.79362E+00	2.47993E+00	1.10867E+00	1.37126E+00	6.06889E-02	1.38000E+00	4.00000E-01
6.50000	6.50000E+00	3.85290E+00	2.48245E+00	1.11247E+00	1.36998E+00	5.36200E-02	1.38000E+00	4.00000E-01
6.60000	6.60000E+00	3.91217E+00	2.48455E+00	1.11599E+00	1.36856E+00	4.70111E-02	1.38000E+00	4.00000E-01
6.70000	6.70000E+00	3.97145E+00	2.48621E+00	1.11925E+00	1.36696E+00	4.14790E-02	1.38000E+00	4.00000E-01
6.80000	6.80000E+00	4.03072E+00	2.48742E+00	1.12223E+00	1.36520E+00	3.75136E-02	1.38000E+00	4.00000E-01
6.90000	6.90000E+00	4.09000E+00	2.48822E+00	1.12494E+00	1.36328E+00	3.54366E-02	1.38000E+00	4.00000E-01
7.00000	7.00000E+00	4.14927E+00	2.48863E+00	1.12739E+00	1.36124E+00	3.53752E-02	1.38000E+00	4.00000E-01
7.10000	7.10000E+00	4.20855E+00	2.48870E+00	1.12958E+00	1.35913E+00	3.72585E-02	1.38000E+00	4.00000E-01
7.20000	7.20000E+00	4.26782E+00	2.48850E+00	1.13152E+00	1.35699E+00	4.08296E-02	1.38000E+00	4.00000E-01
7.30000	7.30000E+00	4.32710E+00	2.48809E+00	1.13324E+00	1.35485E+00	4.56768E-02	1.38000E+00	4.00000E-01
7.40000	7.40000E+00	4.38637E+00	2.48752E+00	1.13476E+00	1.35276E+00	5.12757E-02	1.38000E+00	4.00000E-01
7.50000	7.50000E+00	4.44565E+00	2.48681E+00	1.13611E+00	1.35071E+00	5.70432E-02	1.38000E+00	4.00000E-01
7.60000	7.60000E+00	4.50493E+00	2.48601E+00	1.13730E+00	1.34870E+00	6.23948E-02	1.38000E+00	4 00000E-01
7.70000	7.70000E+00	4.56420E+00	2.48511E+00	1.13838E+00	1.34673E+00	6.68008E-02	1.38000E+00	4.00000E-01
7.80000	7.80000E+00	4.62348E+00	2.48410E+00	1.13935E+00	1.34475E+00	6.98403E-02	1.38000E+00	4.00000E-01
7.90000	7.90000E+00	4.68275E+00	2.48298E+00	1.14022E+00	1.34275E+00	7.12385E-02	1.38000E+00	4.00000E-01
8.00000	8.00000E+00	4.74203E+00	2.48172E+00	1.14101E+00	1.34070E+00	7.08931E-02	1.38000E+00	4.00000E-01
8.10000	8.10000E+00	4.80130E+00	2.48030E+00	1.14171E+00	1.33859E+00	6.88807E-02	1.38000E+00	4.00000E-01
8.20000	8.20000E+00	4.86058E+00	2.47873E+00	1.14233E+00	1.33641E+00	6.54440E-02	1.38000E+00	4.00000E-01
8.30000	8.30000E+00	4.91985E+00	2.47701E+00	1.14286E+00	1.33415E+00	6.09637E-02	1.38000E+00	4.00000E-01
8.40000	8.40000E+00	4.97913E+00	2.47515E+00	1.14330E+00	1.33185E+00	5.59159E-02	1.38000E+00	4.00000E-01
8.50000	8.50000E+00	5.03840E+00	2.47317E+00	1.14365E+00	1.32952E+00	5.08224E-02	1.38000E+00	4.00000E-01
8.60000	8.60000E+00	5.09768E+00	2.47110E+00	1.14392E+00	1.32718E+00	4.61962E-02	1.38000E+00	4.00000E-01
8.70000	8.70000E+00	5.15695E+00	2.46898E+00	1.14412E+00	1.32487E+00	4.24908E-02	1.38000E+00	4.00000E-01
8.80000	8.80000E+00	5.21623E+00	2.46683E+00	1.14425E+00	1.32258E+00	4.00554E-02	1.38000E+00	4.00000E-01
8.90000	8.90000E+00	5.27550E+00	2.46467E+00	1.14433E+00	1.32035E+00	3.91022E-02	1.38000E+00	4.00000E-01
9.00000	9.00000E+00	5.33478E+00	2.46252E+00	1.14436E+00	1.31815E+00	3.96878E-02	1.38000E+00	4.00000E-01
9.10000	9.10000E+00	5.39406E+00	2.46038E+00	1.14437E+00	1.31600E+00	4.17099E-02	1.38000E+00	4 00000E-01
9.20000	9.20000E+00	5.45333E+00	2.45824E+00	1.14436E+00	1.31388E+00	4.49210E-02	1.38000E+00	4.00000E-01
9.30000	9.30000E+00	5.51261E+00	2.45610E+00	1.14434E+00	1.31176E+00	4.89574E-02	1.38000E+00	4.00000E-01
9.40000	9.40000E+00	5.57188E+00	2.45395E+00	1.14431E+00	1.30964E+00	5.33785E-02	1.38000E+00	4.00000E-01
9.50000	9.50000E+00	5.63116E+00	2.45178E+00	1.14427E+00	1.30750E+00	5.77146E-02	1.38000E+00	4 00000E-01

9.60000	9.60000E+00	5.69043E+00	2.44957E+00	1.14423E+00	1.30534E+00	6.15165E-02	1.38000E+00	4.00000E-01
9.70000	9.70000E+00	5.74971E+00	2.44732E+00	1.14418E+00	1.30315E+00	6.44020E-02	1.38000E+00	4.00000E-01
9.80000	9.80000E+00	5.80898E+00	2.44505E+00	1.14411E+00	1.30094E+00	6.60938E-02	1.38000E+00	4.00000E-01
9.90000	9.90000E+00	5.86826E+00	2.44275E+00	1.14403E+00	1.29872E+00	6.64445E-02	1.38000E+00	4.00000E-01
10.00000	1.00000E+01	5.92753E+00	2.44044E+00	1.14393E+00	1.29651E+00	6.54504E-02	1.38000E+00	4.00000E-01
10.10000	1.01000E+01	5.98681E+00	2.43813E+00	1.14382E+00	1.29431E+00	6.32464E-02	1.38000E+00	4.00000E-01

The Mie efficiency factor file `QTOGDT.MIE` used for this case is:

```
4.210730E-03 1.225360E-08
8.424680E-03 1.962430E-07
1.264530E-02 9.9277503-07
1.687640E-02 3.137120E-06
2.112180E-02 7.660350E-06
2.538570E-02 1.588050E-05
2.967270E-02 2.941900E-05
3.398720E-02 5.018030E-05
3.833430E-02 8.035910E-05
4.271900E-02 1.224580E-04
5.162280E-02 2.537840E-04
6.074370E-02 4.698130E-04
7.012950E-02 8.006730E-04
7.983120E-02 1.280870E-03
8.990170E-02 1.949110E-03
1.003960E-01 2.847980E-03
1.113720E-01 4.023820E-03
1.228850E-01 5.526070E-03
1.349940E-01 7.407020E-03
1.477550E-01 9.721070E-03
1.612250E-01 1.252400E-02
1.754550E-01 1.587220E-02
1.904950E-01 1.982180E-02
2.063910E-01 2.442740E-02
2.231800E-01 2.9740603-02
2.408970E-01 3.580950E-02
2.595640E-01 4.267650E-02
2.791960E-01 5.037750E-02
2.998000E-01 5.894030E-02
3.213700E-01 6.838350E-02
3.438910E-01 7.871500E-02
3.673350E-01 8.993220E-02
3.916680E-01 1.020210E-01
4.168420E-01 1.149540E-01
```

4.428060E-01	1.286950E-01
4.695000E-01	1.431970E-01
4.968630E-01	1.584050E-01
5.248310E-01	1.742560E-01
5.533460E-01	1.906830E-01
5.823510E-01	2.076220E-01
6.118020E-01	2.250070E-01
6.416630E-01	2.427800E-01
6.719110E-01	2.608910E-01
7.025380E-01	2.793030E-01
7.335510E-01	2.979920E-01
7.649680E-01	3.169500E-01
7.968220E-01	3.361860E-01
8.291520E-01	3.557230E-01
8.620030E-01	3.756000E-01
8.954180E-01	3.958680E-01
9.294360E-01	4.165830E-01
9.640810E-01	4.378060E-01
9.993610E-01	4.595940E-01
1.035260E+00	4.819970E-01
1.071730E+00	5.050490E-01
1.259260E+00	6.296700E-01
1.442050E+00	7.625530E-01
1.607290E+00	8.895470E-01
1.759930E+00	1.005200E+00
1.912990E+00	1.115570E+00
2.068770E+00	1.226820E+00
2.214590E+00	1.335150E+00
2.339310E+00	1.431230E+00
2.447680E+00	1.512900E+00
2.551660E+00	1.586770E+00
2.653320E+00	1.657980E+00
2.741820E+00	1.722480E+00
2.809020E+00	1.772240E+00
2.861230E+00	1.806420E+00
2.910040E+00	1.832170E+00
2.956670E+00	1.855290E+00
2.990950E+00	1.873240E+00
3.006350E+00	1.879590E+00
3.009870E+00	1.873500E+00

3.012730E+00	1.860770E+00
3.016130E+00	1.846440E+00
3.010830E+00	1.829110E+00
2.991060E+00	1.804370E+00
2.963200E+00	1.772040E+00
2.937430E+00	1.736830E+00
2.915160E+00	1.702570E+00
2.888550E+00	1.668000E+00
2.852410E+00	1.629560E+00
2.811790E+00	1.587250E+00
2.775230E+00	1.545060E+00
2.744220E+00	1.506260E+00
2.712410E+00	1.469830E+00
2.675240E+00	1.432640E+00
2.636310E+00	1.394190E+00
2.602330E+00	1.357330E+00
2.574660E+00	1.324710E+00
2.548320E+00	1.295840E+00
2.519390E+00	1.268270E+00
2.490240E+00	1.241160E+00
2.465860E+00	1.216150E+00
2.447390E+00	1.195070E+00
2.431030E+00	1.177630E+00
2.413530E+00	1.162090E+00
2.396240E+00	1.147600E+00
2.382780E+00	1.135060E+00
2.374070E+00	1.125590E+00
2.367310E+00	1.118950E+00
2.359860E+00	1.113830E+00
2.352420E+00	1.109480E+00
2.347500E+00	1.106370E+00
2.345870E+00	1.105240E+00
2.345560E+00	1.105910E+00
2.344530E+00	1.107430E+00
2.343060E+00	1.109170E+00
2.342880E+00	1.111330E+00
2.344610E+00	1.114370E+00
2.346970E+00	1.118230E+00
2.348470E+00	1.122330E+00
2.349170E+00	1.126180E+00

```
2.350230E+00 1.129860E+00
2.352170E+00 1.133650E+00
2.354230E+00 1.137550E+00
2.355390E+00 1.141250E+00
2.355620E+00 1.144470E+00
2.355690E+00 1.147220E+00
2.356050E+00 1.149710E+00
2.356270E+00 1.151980E+00
2.355710E+00 1.153870E+00
2.354320E+00 1.155250E+00
2.352610E+00 1.156150E+00
2.350940E+00 1.156710E+00
2.349110E+00 1.157010E+00
2.346740E+00 1.156990E+00
2.343790E+00 1.156590E+00
2.340590E+00 1.155850E+00
2.337410E+00 1.154880E+00
2.334170E+00 1.153750E+00
2.330670E+00 1.152460E+00
2.326870E+00 1.151000E+00
2.322980E+00 1.149400E+00
2.319190E+00 1.147730E+00
2.315470E+00 1.146050E+00
2.311710E+00 1.144360E+00
2.307900E+00 1.142680E+00
2.304140E+00 1.141030E+00
2.300550E+00 1.139440E+00
2.297140E+00 1.137950E+00
2.293820E+00 1.136560E+00
2.290590E+00 1.135280E+00
2.287500E+00 1.134110E+00
```

5.1 Wind Profiles

The file WIND.PRO contains a sample wind profile which is read by NOVAE. The three columns are:

Z(km AGL); windspeed(m/s); wind direction(degrees).

0.00	2.73	198.4
0.75	5.61	284.6
1.75	9.66	283.7

2.75	13.43	282.4
3.75	16.94	280.2
4.75	19.48	276.5
5.75	21.70	274.3
6.75	23.89	273.6
7.75	25.89	272.7
8.75	27.83	272.3
9.75	29.07	272.5
10.75	30.20	271.4
11.75	29.42	271.7
12.75	27.81	272.1
13.75	25.75	272.4
14.75	23.14	271.9
15.75	19.77	274.1
16.75	16.06	275.7
17.75	12.93	276.6
18.75	10.87	277.0
19.75	9.74	277.9
20.75	9.65	279.4
21.75	9.27	278.3
22.75	9.44	277.8
23.75	10.01	277.1
24.75	10.70	271.4
25.75	11.83	271.2
26.75	13.06	264.7
27.75	14.06	264.8
28.75	15.55	259.9
30.75	18.02	260.2

5.2 C_n^2 Profiles

The file CN2.PRO contains a sample C_n^2 profile which is read by NOVAE. The two columns are:

Z(km AGL); $C_n^2(\mathrm{m}^{-2/3})$.

0.001	6.3843-13
0.002	2.533E-13
0.004	1.005E-13
0.006	5.855E-14
0.008	3.990E-14
0.010	2.963E-14

0.012	2.324E-14
0.014	1.892E-14
0.016	1.583E-14
0.020	1.176E-14
0.024	9.221E-15
0.028	7.508E-15
0.032	6.284E-15
0.036	5.370E-15
0.040	4.667E-15
0.044	4.110E-15
0.048	3.659E-15
0.052	3.289E-15
0.056	2.980E-15
0.060	2.718E-15
0.064	2.494E-15
0.072	2.131E-15
0.080	1.852E-15
0.100	1.375E-15
0.150	8.010E-16
0.200	5.458E-16
0.250	4.053E-16
0.300	3.663E-16
0.350	3.663E-16
0.400	4.352E-16
0.500	8.500E-16
0.600	8.667E-16
0.800	4.889E-16
1.000	3.141E-16
1.200	2.191E-16
1.400	1.619E-16
1.500	1.414E-16
1.600	1.247E-16
1.800	9.923E-17
2.000	8.100E-17
2.200	6.752E-17
2.400	5.726E-17
2.500	5.303E-17
2.600	4.928E-17
2.800	4.294E-17
3.000	3.783E-17

3.200	3.365E-17
3.400	3.019E-17
3.500	2.867E-17
3.600	2.728E-17
3.800	2.482E-17
4.000	2.273E-17
4.500	1.865E-17
5.000	1.573E-17
5.500	1.357E-17
6.000	1.193E-17
6.500	1.066E-17
7.000	9.643E-18
7.500	8.825E-18
8.000	8.156E-18
9.000	7.137E-18
10.000	6.408E-18
11.000	5.869E-18
12.000	5.458E-18
13.000	5.139E-18
14.000	4.886E-18
15.000	4.681E-18
16.000	4.514E-18
17.000	4.375E-18
18.000	4.259E-18
18.500	4.208E-18
20.000	2.612E-18
22.000	1.383E-18
24.000	7.320E-19
26.000	3.875E-19
28.000	2.052E-19
30.000	1.086E-19

5.3 *a* Profiles

The file `ALPHA.PRO` contains a sample a profile which is read by NOVAE. The two columns are:

Z(km AGL); Absorption(km^{-1}).

0.00	2.41E-03
0.25	2.03E-03
0.50	1.78E-03

0.75	1.60E-03
1.00	1.43E-03
1.50	1.11E-03
2.00	8.44E-04
2.50	6.19E-04
3.00	4.81E-04
3.50	3.81E-04
4.00	2.89E-04
4.50	2.03E-04
5.00	1.46E-04
5.50	1.09E-04
6.00	7.43E-05
6.50	4.56E-05
7.00	3.26E-05
7.50	2.06E-05
8.00	1.05E-05
8.50	7.32E-06
9.00	4.43E-06
9.50	1.96E-06
10.00	1.27E-06
12.50	2.32E-07
15.00	9.04E-08
17.50	4.49E-08
20.00	2.83E-08
22.50	2.02E-08
25.00	1.30E-08
27.50	6.48E-09
30.00	2.77E-09

5.4 Sample Run

Using these auxiliary data files and the second sample data file, **NOVAE02.DAT**, produces the sample output file **NOVAE02.OUT**. **Were is** the sample data file:

```
WAVL         10.6
VIS           7.
NOVAE
LASI        1.000   5.08E+6   1.1E+07    10.0      10.0
LAS2          5.0     1.E-5      1.39    10.0       5.0
ATM1          1.0       1.0      220.    0.00   8.4E-14   -1.07.5     0.
ATM2          0.0    0.1220    0.0450     1.0       1.0     1.OO   3001.0
```

```
ATM3    0.0     1.0     10.0    0.
TARl    4.5     0.0     5.0     4.      1.
TAR2    30.     30.     50.
CTRL    100.0   1.      2.      0.      20.0    0.      0.0
AVB1    0.0     -1.0    0.01    1.0     0.0     1.      2.0
AVB2    0.9     1.0     .99     17.5    0.98    87.5    2.0
AVB3    1.38    0.40    0.54    1.93    408.    1.446   2.5
AVB4    2.0     3162.   0.04    0.25    0.0849  2.55E-4 98.
APRO    0.0-4.495E+00-1.359E-01 4.861E-03-4.619E-04
GO
ATM1    1.0     1.0     220.    0.00    8.4E-14 -1.075  1.
ATM3    1.0     1.0     10.0    0.
TAR1    4.5     0.0     5.0     4.      1.
TAR2    0.      30.     50.
CTRL    100.0   1.      4.      0.      20.0    0.      0.0
APRO    1.0-4.495E+00-1.359E-01 4.861E-03-4.619E-04
WPRO    1.
GO
CTRL    100.0   0.      3.      0.      20.0    0.      0.0
AVB1    0.0     -1.0    0.01    1.0     0.0     1.      3.0
APRO    2.0-4.495E+00-1.359E-01 4.861E-03-4.619E-04
DONE
END
STOP
# THE FOLLOWING IS EOSAEL SOURCE CONTROL INFORMATION YOU CAN SAFELY REMOVE IT
# SCCS  @(#) NOVAEO2.DAT 2.1 02/23/90
```

Here is the sample output file:

```
*********************************************************************************
 YARNING - THIS LIBRARY CONTAINS TECHNICAL DATA YHOSE EXPORT IS RESTRICTED
 BY THE ARMS EXPORT CONTROL ACT (TITLE 22, u.s.c., SEC 2751 ET SEQ.) OR
 EXECUTIVE ORDER 12470.  VIOLATION OF THESE EXPORT LAWS ARE SUBJECT TO
              SEVERE CRIMINAL PEHAUIES.
*********************************************************************************
                 ********************************
                 *                              *
                 *   ELECTRO-OPTICAL SYSTEHS    *
                 *                              *
                 *     ATMOSPHERIC EFFECTS      *
                 *                              *
                 *          LIBRARY             *
                 *                              *
                 * EOSAEL87 REV 2.1   02/23/90  *
```

****

WAVL 10.6

NOTE: THAT THE ABOVE CARD WAS MODIFIED FOR CONSISTENCY TO:

WAVL .1060E+02 .1060E+02 .0000E+00

	BEGINNING	ENDING
WAVENUMBER (CM**-1)	943.396	943.396
WAVELENGTH (MICROMETERS)	10.600	10.600
FREQUENCY (GHZ)	28301.885	28301.885

VISIBILITY

7.00KM

****

* NOVAE *

* HIGH-ENERGY LASER BEAM *

* ATMOSPHERIC PROPAGATION CODE *

* NOT FOR OPERATIONAL USE *

* EOSAEL87 REV 2.1 02/23/90 *

****

******************************** INPUT ********************************

PARTICLE SIZE FACTOR.......... 2.00

CONTROL PARAMETERS

WAVEFORM SPECIFIER (IDBM) 2

SLEW OPTION (IDSLEW) 0

NUMBER OF INTEGRATION STEPS IN PHASE INTEGRAL (NPT) 20

TILT CONTROL OPTION (IDTLCO) 0

OPTIONAL INTERACTION OF LINEAR EFFECTS WITH BLOOMING (IDRSS) . 0

CONTINUOUS WAVE OR REPETITIVE PULSE OPTION (IDCWRP) 1

LASER PARAMETERS

LASER WAVELENGTH (WVLGTH, MICROMETERS) 10.6000

APERTURE DIAMETER (DIAM, METERS) 1.0000

BEAM POWER (POWER, KILOWATTS) .... 5.000E+06

MAXIMUM BEAM POWER DELIVERABLE (POWMAX, KILOWATTS) ..... 1.100E+07

ENERGY PER PULSE (ENGPUL, KILOJOULES) .... 1.0000E+01

MAXIMUM ENERGY DELIVERABLE PER PULSE

(ENGMAX, KILOJOULES) .... 1.0000E+01

PULSE REPETITION RATE (PRF, SEC-1) 5.0000

PULSE DURATION TIME (TO, SECONDS) 1.00E-05

BEAM QUALITY (TIMSDL) 1.3900

ONE SIGMA HIGH FREQUENCY JITTER ANGLE

(THJH, MICRORADIANS) 10.0000

ONE SIGMA LOW FREQUENCY JITTER ANGLE

(THJL, MICRORADIANS) 5.0000

ENVIRONMENTAL PARAMETERS

========================

MAGNITUDE OF WIND AT REFERENCE HEIGHT (WINDO, M/SEC) ... 1.0000

REFERENCE HEIGHT (HWINDO, METERS) 1.0000

WIND DIRECTION (ANGWND, DEGREES) 220.0000

EXPONENT IN WIND POWER LAW (WNDPOW) .... .1429

REFRACTIVE INDEX STRUCTURE CONSTANT

(CNSQO, M**(-2/3)) 8.400E-14

EXPONENT IN REFRACTIVE INDEX STRUCTURE CONSTANT

POWER LAW (CNSQPW)..................................... -1.0750

CN2 PROFILE OPTION (CN2PRO) .... .0000

WIND PROFILE OPTION (WINPRO) .... .0000

QUANTITY COMBINING SEVERAL ATMOSPHERIC VARIABLES

(SCRPTS, M**3/JOULE) 1.650E-09

ABSORPTION COEFFICIENT (ABSOR, 1/KM) .... .1220

SCATTERING COEFFICIENT (ABSSCA, 1/KM) .... .0450

SCALE HEIGHT FOR ABSORPTION COEF. (HA, KM) 1.0000

SCALE HEIGHT FOR SCATTERING COEF. (HS, KM) 1.0000

APERTURE HEIGHT ABOVE GROUND (HTDEV, METERS) 1.0000

TARGET HEIGHT ABOVE GROUND (HTTAR, METERS) 3001.0000

RANGE FROM LASER TO TARGET (RANGE, KM) 4.5000

DEFOCUSING INCREMENT (DRNGFO, KM) .... .0000

RANGE FROM TARGET TO PROJECTED IMPACT POINT (RMT, KM) .. 5.0000

X-COORDINATE OF PROJECTED IMPACT POINT (XT, KM) 4.0000

Y-COORDINATE OF PROJECTED IMPACT POINT (YT, KM) 1.0000

TRAJECTORY ANGLE (TRAJAN, DEGREES) 30.0000

BEARING OF TARGET (BEARAN, DEGREES) 30.0000

ANGULAR SLEW RATE (SLWVEL, RAD/SEC) OR SPEED OF

LASER (M/SEC) OR SPEED OF TARGET (M/SEC)

(DEPENDS ON IDSLN OPTION) 50.0000

RADIUS OF CIRCLE FOR EXPRESSING AVERAGE INTENSITY

(RAV, CENTIMETERS) 100.0000

BREAKDOWN AND VAPORIZATION PARAMETERS

=====================================

BREAKDOWN OPTION (IBRK) 0

AEROSOL TYPE (IAER) .... -1

PRINT OPTION (IPRTOP) 0

RANGE TO LEADING EDGE OF CLOUD (RNGA, KM) .... .90

CLOUD LENGTH (LA, METERS) 1.00

CLOUD TRANSMITTANCE (TA) .... .9900

NUMBER OF PHASE INTEGRAL STEPS IN CLOUD (NPA) 1

AIR TEMPERATURE (TATM, K) 17.5000

PRESSURE (PATM, ATM) .... .9800

RELATIVE HUMIDITY (RELH, %) 87.5000

MASS EXTINCTION COEFFICIENT (MEC, M**2/G) 1.3800

MASS ABSORPTION COEFFICIENT (MAC, M**2/G) .... .4000

ABSORPTION HEATING FRACTION (FAH) .... .5400
STANDARD DEVIATION OF SIZE DISTRIBUTION (SIG) 1.9300
BOILING TEMPERATURE (TBOIL, K) 408.0000
BULK MATERIAL DENSITY (ROA, G/CM**3) 1.4460
BULK MATERIAL SPECIFIC HEAT (CPA, J/G K) 2.5000
VAPOR SPECIFIC HEAT (CPV, J/G K) 2.0000
HEAT OF VAPORIZATION (LHA, J/G) 3162.00
EVAPORATION COEFFICIENT (EPSA) .... .0400
VAPOR DIFFUSION COEFFICIENT (DCA, CM**2/SEC) .... .2500
VAPOR GAS CONSTANT (RGA, J/G K) .... .0849
AIR THERMAL CONDUCTIVITY (KAIR, W/CM K) 2.550E-04
VAPOR MOLECULAR WEIGHT (MV, G/MOLE) 98.0000
RECONDENSATION OPTION (IRECON) 0
EXPONENTIAL AEROSOL SCALING OPTION (EXEXSC) 1
EXACT MIE EFFICIENCY FACTOR OPTION (DATAP) 2

BEAM TYPE IS REPETITIVE PULSE
CALCULATION DOES NOT INCLUDE SRS
BEAM PROFILE IS TRUNCATED GAUSSIAN
AEROSOL TYPE IS DUST/NONVAPORIZING MATERIALS
NO TILT CONTROL (BEAM WANDER INCLUDED)
LINEAR EFFECTS INCLUDED BEFORE BLOOMING CALCULATIONS
DO NOT CHECK FOR BREAKDOWN
EXPONENTIAL AEROSOL EXTINCTION SCALING ASSUMED IN VAPORIZATION MODEL
APPROXIMATE MIE EFFICIENCY FACTORS USED
NEGLIGIBLE RECONDENSATION ASSUMED BETWEEN PULSES

EPS = .9715 ROEV = 1.0955E-02 CND = .7843
DFF = 9.9404E-02 NONEQ = 5.8576E-02 EQUIL = 1.014
DEFAULT VALUES FOR WATER: 2.1818, ,0722, .83, ,5875, 2.139, 1.569

Z (M)	PEAK (KW/CM**2)	AVG (KW/CM**2)	AREA (CM**2)
.0000	1.472124E-02	9.305597E-03	3.396454E+03
37.5000	1.485770E-02	9.391856E-03	3.344767E+03
75.0000	1.500682E-02	9.486118E-03	3.291862E+03
112.5000	1.516191E-02	9.584159E-03	3.239313E+03
150.0000	1.532278E-02	9.685847E-03	3.187193E+03
187.5000	1.548954E-02	9.791255E-03	3.135505E+03
412.5000	1.665224E-02	1.052622E-02	2.834510E+03
637.5000	1.808183E-02	1.142990E-02	2.547063E+03
862.5000	1.985202E-02	1.254887E-02	2.271406E+03
863.5000	1.966057E-02	1.242785E-02	2.270376E+03
1088.5000	2.142313E-02	1.354200E-02	2.046034E+03
1313.5000	2.399728E-02	1.516917E-02	1.798190E+03
1538.5000	2.714392E-02	1.715823E-02	1.568462E+03
1763.5000	3.101528E-02	1.960539E-02	1.356859E+03
1988.5000	3.581374E-02	2.263860E-02	1.163392E+03
2213.5000	4.180747E-02	2.642736E-02	9.880774E+02
2438.5000	4.934759E-02	3.119363E-02	8.309362E+02

2663.5000	5.887954E-02	3.721897E-02	6.919987E+02
2888.5000	7.092854E-02	4.483539E-02	5.713073E+02
3113.5000	8.600856E-02	5.436778E-02	4.689231E+02
3338.5000	1.043505E-01	6.596208E-02	3.849342E+02
3563.5000	1.252962E-01	7.920234E-02	3.194670E+02
3788.5000	1.463479E-01	9.250953E-02	2.726917E+02
4013.5000	1.625927E-01	1.027782E-01	2.448127E+02
4238.5000	1.682752E-01	1.063702E-01	2.360193E+02
4463.5000	1.608746E-01	1.016921E-01	2.464040E+02
4500.0000	1.585793E-01	1.002412E-01	2.498947E+02

** OUTPUT **

RP OPTION

KEY: DL = DIFFRACTION-LIMITED T = TURBULENCE J = JITTER B = BLOOMING O = OPTIMUM POWER

	DL	+ TJ	+ B	+ BTJ	+ O	+ BTJO
RADIUS OF EXP(-1) BEAM (CM)	4.314E+00	8.355E+00	5.015E+00	8.919E+00	5.015E+00	8.919E+00
AREA OF EXP(-1) BEAM (CM**2)	5.848E+01	2.193E+02	7.901E+01	2.499E+02	7.901E+01	2.499E+02
TIME AVERAGE OF SPATIAL PEAK INTENSITY (KW/CM**2)	6.776E-01	1.807E-01	5.015E-01	1.586E-01	5.015E-01	1.586E-01
TIME AVERAGE OF SPATIAL AVERAGE INTENSITY OVER CIRCLE OF EXP(-1) RADIUS (KW/CM**2)	4.283E-01	1.142E-01	3.170E-01	1.002E-01	3.170E-01	1.002E-01
TIME AVERAGE OF SPATIAL AVERAGE INTENSITY OVER CIRCLE OF SPECIFIED RADIUS RAV (KW/CM**2)	1.261E-03	1.261E-03	1.261E-03	1.261E-03	1.261E-03	1.261E-03
FLUENCE (KJ/CM**2)	1.355E-01	3.614E-02	1.003E-01	3.172E-02	1.003E-01	3.172E-02
PEAK INTENSITY PER PULSE (MW/CM**2)	1.355E+01	3.614E+00	1.003E+01	3.172E+00	1.003E+01	3.172E+00

OPTIMUM ENERGY PER PULSE (KJOULE)

1.000E+01 1.000E+01

FRACTION OF INITIAL POWER PROPAGATED TO RANGE OF INTEREST = 7.9256E-01

PHICON = 1.6875E+06

ZETI (KM)	ALPABS (1/KM)	ALPEXT (1/KM)	BZETA	XB	HBZ	SFBD	ALPBD (1/KM)	BZETJB
.00	,12200	.16700	1.0000	0.00000E+00	1.0000	1.0000	0.00000E+00	1.0000
.04	.11899	,16288	,99391	.33513	1.0000	1.0000	0.00000E+00	.99391
.08	,11605	,15886	,98801	,54995	1.0109	1.0000	0.00000E+00	.98801
.11	.11318	,15493	.98228	,75671	1.0182	1.0000	0.00000E+00	.98228
.15	.11039	.15111	,97673	.96063	1.0254	1.0000	0.00000E+00	.97673
.19	.10766	.14738	,97135	1.1618	1.0329	1.0000	0.00000E+00	,97135
.41	9.26678E-02	,12685	,94402	2.3164	1.0404	1.0000	0.00000E+00	.94402
.64	7.97599E-02	.10918	.92111	3.2126	1.0884	1.0000	0.00000E+00	,92111
.86	6.86500E-02	9.39717E-02	,90184	3.6862	1.1311	1.0000	0.00000E+00	.90184
.86	1.6417	10.144	,89274	3.7005	1.1556	1.0000	0.00000E+00	.89274
1.09	5.90482E-02	8.08283E-02	,87665	6.8291	1.1563	1.0000	0.00000E+00	.87665
1.31	5.08233E-02	6.95696E-02	,86303	6.8291	1.3511	1.0000	0.00000E+00	.86303

154	4.37440E-02	5.98791E-02	.85148	6.8291	1.3511	1.0000	0.00000E+00	.85148
1.76	3.76508E-02	5.15384E-02	.84167	6.8291	1.3511	1.0000	0.00000E+00	.84167
1.99	3.24063E-02	4.43595E-02	.83331	6.8291	1.3511	1.0000	0.00000E+00	.83331
2.21	2.78924E-02	3.81806E-02	.82618	6.8291	1.3511	1.0000	0.00000E+00	.82618
2 44	2.40072E-02	3.28623E-02	,82009	6.8291	1.3511	1.0000	0.00000E+00	.82009
2.66	2.06632E-02	2.82849E-02	.81489	6.8291	1.3511	1.0000	0.00000E+00	.81489
2.89	1.77850E-02	2.43450E-02	.81044	6.8291	1.3511	1.0000	0.00000E+00	.81044
3.11	1.53077E-02	2.09539E-02	.80663	6.8291	1.3511	1.0000	0.00000E+00	.80663
3.34	1.31754E-02	1.80352E-02	,80336	6.8291	1.3511	1.0000	0.00000E+00	.80336
3.56	1.13402E-02	1.55231E-02	.80056	6.8291	1.3511	1.0000	0.00000E+00	.80056
3.79	9.76060E-03	1.33608E-02	,79816	6.8291	1.3511	1.0000	0.00000E+00	.79816
4.01	8.40103E-03	1.14998E-02	,79609	6.8291	1.3511	1.0000	0.00000E+00	.79609
4.24	7.23083E-03	9.89795E-03	.79432	6.8291	1.3511	1.0000	0.00000E+00	.79432
4.46	6.22364E-03	8.51924E-03	,79280	6.8291	1.3511	1.0000	0.00000E+00	.79280
4.50	6.07402E-03	8.31444E-03	,79256	6.8291	1.3511	1.0000	0.00000E+00	.79256

VOL EXT. COEF = 1.0050E-02

VOL ABS COEF = 2.9131E-03

MASS CONC = 7283.

MASS CL = 7283.

MASS OPTICAL DEPTH = 1.0050E-02

NORM.D RANGE = ,1917

** END OF CASE 1 **

****************************** INPUT ******************************

PARTICLE SIZE FACTOR......... 2.00

CONTROL PARAMETERS

WAVEFORM SPECIFIER (IDBM) 4

SLEW OPTION (IDSLEW) 0

NUMBER OF INTEGRATION STEPS IN PHASE INTEGRAL (NPT) 20

TILT CONTROL OPTION (IDTLCO) 0

OPTIONAL INTERACTION OF LINEAR EFFECTS WITH BLOOMING (IDRSS) . 0

CONTINUOUS UAVE OR REPETITIVE PULSE OPTION (IDCWRP) 1

LASER PARAMETERS

LASER WAVELENGTH (WVLGTH, MICROMETERS) 10.6000

APERTURE DIAMETER (DIAM, METED) 1.0000

BEAN POWER (POWER, KILOVATTS) .... 5.000E+06

MAXIMUM BEAN POWER DELIVERABLE (POWMAX, KILOWATTS) ..... 1.100E+07

ENERGY PER PULSE (ENGPUL, KILOJOULES) ....1.0000E+01

MAXIMUM ENERGY DELIVERABLE PER PULSE

(ENGMAX, KILOJOULES) ....1.0000E+01

PULSE REPETITION RATE (PRF, SEC-1) 5.0000

PULSE DURATION TIME (TO, SECONDS) 1.000E-05

BEAM QUALITY (TIMSDL) 1.3900

ONE SIGMA HIGH FREQUENCY JITTER ANGLE

(THJH, MICRORADIANS) 10.0000

ONE SIGMA LOU FREQUENCY JITTER ANGLE

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   (THJL . MICRORADIANS) ................................  5.0000
                ENVIRONMENTAL PARAMETERS
                ========================
MAGNITUDE OF UIND AT REFERENCE HEIGHT (WINDO, M/SEC) ...   1.0000
REFERENCE HEIGHT (HWINDO, METERS) .......................  1.0000
WIND DIRECTION (ANGWND, DEGREES) ....................... 220.0000
EXPONENT IN WIND POWER LAU (WNDPOW) ....................    .1429
REFRACTIVE INDEX STRUCTURE CONSTANT
   (CNSQO, M**(-2/3)) ................................. 8.400E-14
EXPONENT IN REFRACTIVE INDEX STRUCTURE CONSTANT
   POWER LAW (CNSQPW).................................. -1.0750
CN2 PROFILE OPTION (CN2PRO) ..............................1.0000
UIND PROFILE OPTION (WINPRO) . ...........................1.0000
QUANTITY COMBINING SEVERAL ATMOSPHERIC VARIABLES
   (SCRPTS, M**3/JOULE) .............................. 1.650E-09
ABSORPTION COEFFICIENT (ABSOR, 1/KM) ..................    .1220
SCATTERING COEFFICIENT (ABSSCA, 1/KM) .................    .0450
SCALE HEIGHT FOR ABSORPTION COEF.(HA, KM) .............   1.0000
SCALE HEIGHT FOR SCATTERING COEF. (HS, KM) ............   1.0000
APERTURE HEIGHT ABOVE GROUND(HTDEV, METERS) ...........   1.0000
TARGET HEIGHT ABOVE GROUND (HTTAR, METERS) ............ 3001.0000
RANGE FROM LASER TO TARGET(RANGE, KM) .................   4.5000
DEFOCUSING INCREMENT (DRNGFO, KM) .....................    .0000
RANGE FROM TARGET TO PROJECTED IHPACT POINT (RMT, KM) ..  5.0000
X-COORDINATE OF PROJECTED IMPACT POINT(XT, KM) ........   4.0000
Y-COORDINATE OF PROJECTED IMPACT POINT (YT, KM) .......   1.0000
TRAJECTORY ANGLE(TRAJAN, DEGREES) .....................    .0000
BEARING OF TARGET (BEARAN. DEGREES) ...................  30.0000
ANGULAR SLEW RATE (SLUVEL, RAD/SEC) OR SPEED OF
   LASER (M/SEC) OR SPEED OF TARGET (M/SEC)
   (DEPENDS ON IDSLEU OPTION) .........................  50.0000
RADIUS OF CIRCLE FOR EXPRESSING AVERAGE INTENSITY
   (RAV, CENTIMETERS) ................................. 100.0000
           BREAKDWN AND VAPORIZATION PARAMETERS
           ====================================
BREAKDOWN OPTION (IBRK) ...............................        0
AEROSOL TYPE (IAER) ...................................       -1
PRINT OPTION(IPRTOP) ..................................        0
RANGE TO LEADING EDGE OF CLOUD(RNGA, KM) ..............      .90
CLOUD LENGTH(LA, METERS) ..............................     1.00
CLOUD TRANSHITTANCE (TA) ..............................    .9900
NUMBER OF PHASE INTEGRAL STEPS IN CLOUD (NPA) .........        1
AIR TEMPERATURE (TATM, K) .............................  17.5000
PRESSURE(PATH, ATM) ...................................    .9800
RELATIVE HUMIDITY (RELH, %) ...........................  87.5000
MASS EXTIHCTION COEFFICIENT (MEC, M**2/G) .............   1.3800
MASS ABSORPTION COEFFICIENT (MAC, M**2/G) .............    .4000
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ABSORPTION HEATING FRACTION (FAH) .... .5400
STANDARD DEVIATION OF SIZE DISTRIBUTION (SIG) 1.9300
BOILING TEMPERATURE (TBOIL, K) 408.0000
BULK MATERIAL DENSITY (ROA, G/CM**3) 1.4460
BULK MATERIAL SPECIFIC HEAT (CPA, J/G K) 2.5000
VAPOR SPECIFIC HEAT (CPV, JIG K) 2.0000
HEAT OF VAPORIZATION (LHA, J/G) 3162.00
EVAPORATION COEFFICIENT (EPSA) .... .0400
VAPOR DIFFUSION COEFFICIENT (DCA, CM**2/SEC) .... ,2500
VAPOR GAS CONSTANT (RGA, J/G K) .... ,0849
AIR THERMAL CONDUCTIVITY (KAIR, W/CM K) 2.550E-04
VAPOR MOLECULAR WEIGHT (MV, G/MOLE) 98.0000
RECONDENSATION OPTION (IRECON) 0
EXPONENTIAL AEROSOL SCALING OPTION (EXEXSC) 1
EXACT MIE EFFICIENCY FACTOR OPTION (DATAP) 2

BEAM TYPE IS REPETITIVE PULSE
CALCULATION DOES INCLUDE SRS
DOES NOT INCLUDE BREAKDOWN AND EXTINCTION ATTENUATION IN ENERGY OR POWER PASSED TO SRS ROUTINE
SRS CALCULATION IS VIBRATIONAL
BEAM PROFILE IS UNIFORM CIRCULAR, 10 PERCENT OBSCURATION
AEROSOL TYPE IS DUST/NONVAPORIZING MATERIALS
NO TILT CONTROL (BEAM WANDER INCLUDED)
LINEAR EFFECTS INCLUDED BEFORE BLOOMING CALCULATIONS
DO NOT CHECK FOR BREAKDOWN
EXPONENTIAL AEROSOL EXTINCTION SCALING ASSUMED IN VAPORIZATION MODEL
APPROXIMATE MIE EFFICIENCY FACTORS USED
NEGLIGIBLE RECONDENSATION ASSUMED BETWEEN PULSES
EPS = ,9715 REV = 1.0955E-02 CND = ,7843
DFF = 9.9404E-02 NONEQ = 5.8576E-02 EQUIL = 1.014
DEFAULT VALUES FOR WATER: 2.1818,.0722, .83, ,5875,2.139,1.569

Z (M)	PEAK (KW/CM**2)	AVG (KW/CM**2)	AREA (CM**2)
0000	1.870761E-02	1.182546E-02	2.672709E+03
37.5000	1.898287E-02	1.199946E-02	2.628525E+03
75.0000	1.926542E-02	1.217807E-02	2.584746E+03
112.5000	1.955545E-02	1.236140E-02	2.541375E+03
150.0000	1.985316E-02	1 254959E-02	2.498413E+03
187.5000	2.015877E-02	1.274277E-02	2.455864E+03
412.5000	2.218104E-02	1.402109E-02	2.209505E+03
637.5000	2.454092E-02	1.551282E-02	1.979159E+03
862.5000	2.723969E-02	1.721877E-02	1.768824E+03
863.5000	2.697970E-02	1.705443E-02	1.767947E+03
1088.5000	2.976434E-02	1.881465E-02	1.591077E+03
1313 5000	3.108707E-02	1.965078E-02	1.513575E+03
1538.5000	2.200889E-02	1.391227E-02	2.125472E+03
1763.5000	1.920013E-02	1.213680E-02	2.423577E+03
1988.5000	1.621720E-02	1.025122E-02	2.855613E+03

2213.5000	1.343959E-02	8.495442E-03	3.430701E+03
2438.5000	1.104743E-02	6.983307E-03	4.156791E+03
2663.5000	9.076296E-03	5.737314E-03	5.040782E+03
2888.5000	7.488451E-03	4.733604E-03	6.088654E+03
3113.5000	6.221117E-03	3.932497E-03	7.305608E+03
3338.5000	5.210694E-03	3.293787E-03	8.696263E+03
3563.5000	4.402032E-03	2.782615E-03	1.026501E+04
3788.5000	3.750669E-03	2.370875E-03	1.201599E+04
4013.5000	3.221929E-03	2.036648E-03	1.395312E+04
4238.5000	2.789178E-03	1.763097E-03	1.607999E+04
4463.5000	2.432032%-03	1.537338E-03	1.839999E+04

NO RAUAN CONVERSION Z = 4.50E+03

4500.0000	2.380088E-03	1.504503E-03	1.879476E+04

** OUTPUT **

RP OPTION

KEY: DL = DIFFRACTION-LIMITED T = TURBULENCE J = JITTER B = BLOOMING O = OPTIMUM POWER

	DL	+ TJ	+ B	• BTJ	+ O	• BTJO
RADIUS OF EXP(-1) BEAM (CM)	5.131E+00	7.733E+01	5.145E+00	7.735E+01	5.145E+00	7.735E+01
AREA OF EXP(-1) BEAM (CM**2)	8.272E+01	1.879E+04	8.315E+01	1.879E+04	8.315E+01	1.879E+04
TIME AVERAGE OF SPATIAL PEAK INTENSITY (KW/CM**2)	5.408E-01	2.381E-03	5.380E-01	2.380E-03	5.380E-01	2.380E-03
TIUE AVERAGE OF SPATIAL AVERAGE INTENSITY OVER CIRCLE OF EXP(-1) RADIUS (KW/CM**2)	3.418E-01	1.505E-03	3.401E-01	1.505E-03	3.401E-01	1.505E-03
TIUE AVERAGE OF SPATIAL AVERAGE INTENSITY OVER CIRCLE OF SPECIFIED RADIUS RAV (KW/CM**2)	1.424E-03	1.156E-03	1.424E-03	1.156E-03	1.424E-03	1.156E-03
FLUENCE (KJ/CM**2)	1.082E-01	4.762E-04	1.076E-01	4.760E-04	1.076E-01	4.760E-04
PEAK INTENSITY PER PULSE (MW/CM**2)	1.082E+01	4.762E-02	1.076E+01	4.760E-02	1.076E+01	4.760E-02

OPTIMUM ENERGY PER PULSE (KJOULE)

1.000E+01 1.000E+01

FRACTION OF INITIAL POWER PROPAGATED TO RANGE OF INTEREST = 8.9466E-01

PHICON = 3.5645E+05

ZETI (KM)	ALPABS (1/KM)	ALPEXT (1/KM)	BZETA	XB	HBZ	SFBD	ALPBD (1/KM)	BZETAB
.00	1.11647E-02	5.61647E-02	1.0000	0.00000E+00	1.0000	1.0000	0.00000E+00	1.000)
.04	1.11268E-02	5.50158E-02	,99794	1.76427E-02	1.0000	1.0000	0.00000E+00	.99791
.08	1.10892E-02	5.38945E-02	,99592	3.54870E-02	1.0003	1.0000	0.00000E+00	.99592
.11	1.10518E-02	5.28002E-02	,99395	5.35386E-02	1.0007	1.0000	0.00000E+00	.99395
.15	1.10145E-02	5.17322E-02	.99203	7.18035E-02	1.0010	1.0000	0.00000E+00	.99203
.19	1.09774E-02	5.06898E-02	.99014	9.02877E-02	1.0014	1.0000	0.00000E+00	.99014
.41	1.07590E-02	4.49397E-02	,98018	.20650	1.0017	1.0000	0.00000E+00	.98018
.64	1.05470E-02	3.99666E-02	,97141	.26414	1.0040	1.0000	0.00000E+00	,9714:.
.86	1.03412E-02	3.56629E-02	.96364	.26414	1.0051	1.0000	0.00000E+00	.96364

.86	1.5834	10.086	.95397	.26414	1.0051	1.0000	0.00000E+00	.95397
1.09	1.01403E-02	3.19204E-02	.94715	.26414	1.0051	1.0000	0.00000E+00	.94715
1.31	9.94599E-03	2.86923E-02	.94105	.26414	1.0051	1.0000	0.00000E+00	.94105
1.54	9.75698E-03	2.58921E-02	.93559	.26414	1.0051	1.0000	0.00000E+00	.93559
1.76	9.57304E-03	2.34606E-02	.93066	.26414	1.0051	1.0000	0.00000E+00	.93066
1.99	9.39393E-03	2.13471E-02	.92620	.26414	1.0051	1.0000	0.00000E+00	.92620
2.21	9.21943E-03	1.95076E-02	.92214	.26414	1.0051	1.0000	0.00000E+00	.92214
2.44	9.04932E-03	1.79044E-02	.91844	.26414	1.0051	1.0000	0.00000E+00	.91844
2.66	8.88339E-03	1.65051E-02	.91503	.26414	1.0051	1.0000	0.00000E+00	.91503
2.89	8.72144E-03	1.52815E-02	.91189	.26414	1.0051	1.0000	0.00000E+00	.91189
3.11	8.56329E-03	1.42098E-02	.90898	.26414	1.0051	1.0000	0.00000E+00	.90898
3.34	8.40876E-03	1.32685E-02	.90627	.26414	1.0051	1.0000	0.00000E+00	.90527
3.56	8.25758E-03	1.24405E-02	.90374	.26414	1.0051	1.0000	0.00000E+00	.90374
3.79	8.10989E-03	1.17101E-02	.90136	.26414	1.0051	1.0000	0.00000E+00	.90136
4.01	7.96522E-03	1.10640E-02	.89912	.26414	1.0051	1.0000	0.00000E+00	.89912
4.24	7.82355E-03	1.04907E-02	.89700	.26414	1.0051	1.0000	0.00000E+00	.89700
4.46	7.68472E-03	9.98033E-03	.89499	.26414	1.0051	1.0000	0.00000E+00	.89499
4.50	7.66246E-03	9.90288E-03	.89466	.26414	1.0051	1.0000	0.00000E+00	.89466

VOL EXT. COEF = 1.0050E-02

VOL ABS COEF = 2.9131E-03

MASS CONC = 7283.

MASS CL = 7283.

MASS OPTICAL DEPTH = 1.0050E-02

NORM.D RANGE = .1917

** END OF CASE 2 **

********************************** INPUT **********************************

PARTICLE SIZE FACTOR......... 2.00

CONTROL PARAMETERS

==================

WAVEFORM SPECIFIER (IDBM) 3

SLEW OPTION (IDSLEW) 0

NUMBER OF INTEGRATION STEPS IN PHASE INTEGRAL (NPT) 20

TILT CONTROL OPTION (IDTLCO) 0

OPTIONAL INTERACTION OF LINEAR EFFECTS WITH BLOOMING (IDRSS) . 0

CONTINUOUS WAVE OR REPETITIVE PULSE OPTION (IDCYRP) 0

LASER PARAMETERS

================

LASER WAVELENGTH (WVLGTH, MICROMETERS) 10.6000

APERTURE DIAMETER (DIAM, METERS) 1.0000

BEAM POWER (POWER, KILOWATTS) .... 5.080E+06

MAXIMUM BEAM POWER DELIVERABLE (POWMAX, KILOWATTS) ..... 1.100E+07

ENERGY PER PULSE (ENGPUL, KILOJOULES) ....1.0000E+01

MAXIMUM ENERGY DELIVERABLE PER PULSE

(ENGMAX, KILOJOULES) ....1.0000E+01

PULSE REPETITION RATE (PRF, SEC-1) 5.0000

PULSE DURATION TIME (TO, SECONDS) 1.000E-05

BEAM QUALITY(TIMSDL) 1.3900

```
ONE SIGMA HIGH FREQUENCY JITTER ANGLE
   (THJH, MICRORADIANS) ................................  10.0000
ONE SIGMA LOW FREQUENCY JITTER ANGLE
   (THJL, MICRORADIANS) ................................   5.0000
                 ENVIRONMENTAL PARAMETERS
                 ------------------------
MAGNITUDE OF WIND AT REFERENCE HEIGHT (WINDO, M/SEC) ...   1.0000
REFERENCE HEIGHT (HWINDO, METERS) ......................   1.0000
VIND DIRECTION(ANGVND, DEGREES) ....................... 281.8478
EXPONENT IN WIND POWER LAW (WNDPOW) ....................    .1429
REFRACTIVE INDEX STRUCTURE CONSTANT
   (CNSQO, M**(-2/3)) ..................................6.400E-14
EXPONENT IN REFRACTIVE INDEX STRUCTURE CONSTANT
   POWER LAW (CNSQPW)...................................  -1.0750
CN2 PROFILE OPTION (CN2PRO) ..............................1.0000
WIND PROFILE OPTION (WINPRO) .............................1.0000
QUANTITY COMBINING SEVERAL ATMOSPHERIC VARIABLES
   (SCRPTS, M**3/JOULE) .................................1.650E-09
ABSORPTION COEFFICIENT (ABSOR, 1/KM) ...................    .1220
SCATTERING COEFFICIENT (ABSSCA, 1/KM) ..................    .0450
SCALE HEIGHT FOR ABSORPTION COEF. (HA, KM) .............   1.0000
SCALE HEIGHT FOR SCATTERING COEF. (HS, KM) .............   1.0000
APERTURE HEIGHT ABOVE GROUND(HTDEV, METERS) ............   1.0000
TARGET HEIGHT ABOVE GROUND (HTTAR, METERS) ............ 3001.0000
RANGE FROM LASER TO TARGET(RANGE, KM) ..................   4.5000
DEFOCUSING INCREMENT (DRNGFO, KM) ......................    .0000
RANGE FROM TARGET TO PROJECTED IMPACT POINT (RMT, KM) ..   5.0000
X-COORDINATE OF PROJECTED IMPACT POINT(XT, KM) .........   4.0000
Y-COORDINATE OF PROJECTED IMPACT POINT(YT, KM) .........   1.0000
TRAJECTORY ANGLE (TRAJAN, DEGREES) .....................    .0000
BEARING OF TARGET (BEARAN, DEGREES) ....................  30.0000
ANGULAR SLEW RATE(SLWEL, RAD/SEC) OR SPEED OF
   LASER (M/SEC) OR SPEED OF TARGET (M/SEC)
   (DEPENDS ON IDSLEV OPTION) ..........................  50.0000
RADIUS OF CIRCLE FOR EXPRESSING AVERAGE INTENSITY
   (RAV, CENTIMETERS) .................................. 100.0000
            BREAKDOWN AND VAPORIZATION PARAMETEE
            ====================================
BREAKDOWN OPTION (IBRK) ................................        0
AEROSOL TYPE (IAER) ....................................       -1
PRINT OPTION(IPRTOP) ...................................        0
RANGE TO LEADING EDGE OF CLOUD (RNGA, KM) ..............      .90
CLOUD LENGTH(LA, METERS) ...............................     1.00
CLOUD TRANSMITTANCE (TA) ...............................    .9900
NUMBER OF PHASE INTEGRAL STEPS IN CLOUD (NPA) ..........        1
AIR TEMPERATURE (TATM, K) ..............................  17.5000
PRESSURE(PATM, ATM) ....................................    .9800
```

```
RELATIVE HUMIDITY (RELH, %) ............................ 87.5000
MASS EXTINCTION COEFFICIENT (MEC, M**2/G) ............. 1.3800
MASS ABSORPTION COEFFICIENT (MAC, M**2/G) ............. .4000
ABSORPTION HEATING FRACTION (FAH) ...................... .5400
STANDARD DEVIATION OF SIZE DISTRIBUTION (SIG) .......... 1.9300
BOILING TEMPERATURE (TBOIL, K) ......................... 408.0000
BULK MATERIAL DENSITY (ROA, G/CM**3) .................. 1.4460
BULK MATERIAL SPECIFIC HEAT (CPA, J/G K) .............. 2.5000
VAPOR SPECIFIC HEAT (CPV, J/G K) ....................... 2.0000
HEAT OF VAPORIZATION (LHA, J/G) ........................ 3162.00
EVAPORATION COEFFICIENT (EPSA) ......................... .0400
VAPOR DIFFUSION COEFFICIENT (DCA, CM**2/SEC) ........... .2500
VAPOR GAS CONSTANT (RGA, J/G K) ........................ .0849
AIR THERMAL CONDUCTIVITY (KAIR, W/CM K) ................ 2.550E-04
VAPOR MOLECULAR WEIGHT (MV, G/MOLE) .................... 98.0000
RECONDENSATION OPTION (IRECON) ......................... 0
EXPONENTIAL AEROSOL SCALING OPTION (EXEXSC) ............ 1
EXACT MIE EFFICIENCY FACTOR OPTION (DATAP) ............. 3
BEAM TYPE IS CONTINUOUS WAVE
CALCULATION DOES    INCLUDE SRS
DOES NOT INCLUDE BREAKDOWN AND EXTINCTION          ATTENUATION IN ENERGY OR POWER PASSED TO SRS ROUTINE
SRS CALCULATION IS VIBRATIONAL
BEAM PROFILE IS UNIFORM CIRCULAR
AEROSOL TYPE IS DUST/NONVAPORIZING MATERIALS
NO TILT CONTROL (BEAM WANDER INCLUDED)
LINEAR EFFECTS INCLUDED BEFORE BLOOMING CALCULATIONS
DO NOT CHECK FOR BREAKDOWN
EXPONENTIAL AEROSOL EXTINCTION SCALING ASSUMED IN VAPORIZATION MODEL
CALL AGAUS TO CALCULATE MIE EFFICIENCY FACTORS.
NEGLIGIBLE RECONDENSATION ASSUMED BETWEEN PULSES
NON-VAPORIZING MATERIALS IN CLOUD.
NO CALL TO AGAUS NECESSARY.
EPS  =  .9715    ROEV  =  1.0955E-02 CND  =  .7843
DFF  =  9.9404E-02 NONEQ =  5.8576E-02 EQUIL =  1.014
DEFAULT VALUES FOR WATER: 2.1818, .0722, .83, .5875, 2.139, 1.569
 Z= .0  ALPHA= 2.40999E-06
    Z          PEAK          AVG           AREA
   (M)      (KW/CM**2)    (KW/CM**2)     (CM**2)
     .0000  1.293612E+03  8.177185E+02  3.926990E+03
 Z= 2.50000E-02  ALPHA= 2.37199E-06
   37.5000  5.953927E+02  3.763600E+02  8.517396E+03
 Z= 5.00000E-02  ALPHA= 2.33400E-06
   75.0000  3.498149E+02  2.211252E+02  1.447227E+04
 Z= 7.50000E-02  ALPHA= 2.29600E-06
  112.5000  2.339040E+02  1.478556E+02  2.160828E+04
 Z= .1  ALPHA= 2.25799E-06
  150.0000  1.695341E+02  1.071660E+02  2.976466E+04
```

```
Z= .125  ALPHA= 2.22000E-06
  187.5000   1.298502E+02   8.208099E+01   3.880006E+04
Z= .275  ALPHA= 2.00500E-06
  412.5000   4.732026E+01   2.991211E+01   1.056068E+05
Z= .425  ALPHA= 1.85500E-06
  637.5000   2.690626E+01   1.700800E+01   1.844293E+05
Z= ,574999  ALPHA= 1.72600E-06
  862.5000   1.836311E+01   1.160770E+01   2.685924E+05
Z= ,575666  ALPHA= 1.72552E-06
  863.5000   1.024839E+01   6.478219E+00   4.764396E+05
Z= ,725666  ALPHA= 1.61751E-06
 1088.5000   3.296978E-03   2.084088E-03   1.473198E+09
Z= ,875666  ALPHA= 1.51454E-06
 1313.5000   3.270474E-03   2.067334E-03   1.478382E+09
Z= 1.0257  ALPHA= 1.41357E-06
 1538.5000   3.247785E-03   2.052992E-03   1.482844E+09
Z= 1.1757  ALPHA= 1.31757E-06
 1763.5000   3.229616E-03   2.041507E-03   1.486092E+09
Z= 1.3257  ALPHA= 1.22157E-06
 1988.5000   3.214501E-03   2.031952E-03   1.488661E+09
Z= 1.4757  ALPHA= 1.12557E-06
 2213.5000   3.201994E-03   2.024046E-03   1.490643E+09
Z= 1.6257  ALPHA= 1.04314E-06
 2438.5000   3.191618E-03   2.017488E-03   1.492162E+09
Z= 1.7757  ALPHA= 9.63345E-07
 2663.5000   3.182943E-03   2.012004E-03   1.493341E+09
Z= 1.9257  ALPHA= 8.83545E-07
 2888.5000   3.175617E-03   2.007373E-03   1.494282E+09
Z= 2.0757  ALPHA= 8.09950E-07
 3113.5000   3.169348E-03   2.003410E-03   1.495064E+09
Z= 2.2257  ALPHA= 7.42450E-07
 3338.5000   3.163912E-03   1.999974E-03   1.495746E+09
Z= 2.3757  ALPHA= 6.74950E-07
 3563.5000   3.159144E-03   1.996960E-03   1.496367E+09
Z= 2.5257  ALPHA- 6.11915E-07
 3788.5000   3.154912E-03   1.994285E-03   1.496955E+09
Z= 2.6757  ALPHA= 5.70515E-07
 40W.5000   3.151105E-03   1.991878E-03   1.497527E+09
Z= 2.8257  ALPHA= 5.29115E-07
 4238.5000   3.147649E-03   1.989694E-03   1.498093E+09
Z= 2.9757  ALPHA= 4.87715E-07
 4463.5000   3.144487E-03   1.987695E-03   1.498661E+09
Z= 3.0  ALPHA= 4.81000E-07
NO RAMAN COWVERSION  Z = 4.50E+03
 4500.0000   3.143981E-03   1.987375E-03   1.498753E+09
**************************************************** OUTPUT ******************************************************
                                                CV OPTION
```

KEY: DL = DIFFRACTION-LIMITED T = TURBULENCE J = JITTER B = BLOOMING O = OPTIMUM POWER

	DL	+ TJ	ı B	• BTJ	• O	+ BTJO
RADIUS OF EX~(-I)BEAN (CM)	4.400E+00	7.729E+01	2.213E+04	2.184E+04	8.885E+00	1.468E+02
AREA OF EXP(-1) BEAN (CM**2)	6.090E+01	1.877E+04	1.538E+09	1.499E+09	2.480E+02	6.768E+04
TINE AVERAGE OF SPATIAL PEAK INTENSITY (KW/CM**2)	7.738E+04	2.511E+02	3.064E-03	3.144E-03	3.782E+00	2.470E-01
TINE AVERAGE OF SPATIAL AVERAGE INTENSITY OVER CIRCLE OF EXP(-1) RADIUS (KW/CM**2)	4.891E+04	1.587E+02	1.937E-03	1.987E-03	2.390E+00	1.562E-01
TINE AVERAGE OF SPATIAL AVERAGE INTENSITY OVER CIRCLE OF SPECIFIED RADIUS RAV (KW/CM**2)	1.500E+02	1.219E+02	3.0			

66E-03 3.147E-03 2.985E-02 1.976E-01

OPTIMUM POWER AT APERTURE (KW)

1.011E+03 1.803E+04

FRACTION OF INITIAL POWER PROPAGATED TO RANGE OF INTEREST = 9.2757E-01

PHICON = 3.3700E+06

ZETI (KM)	ALPABS (1/KM)	ALPEXT (1/KM)	BZETA	XB	HBZ	SFBD	ALPBD (1/KM)	BZETAB
.00	2.41000E-03	4.74100E-02	1.0000	0.00000E+00	1.0000	1.0000	0.00000E+00	1.0300
.04	2.37200E-03	4.62609E-02	.99827	326.97	1.0000	1.0000	0.00000E+00	.99327
.08	2.33400E-03	4.51393E-02	,99658	640.09	23.033	1.0000	0.00000E+00	.99658
11	2.29600E-03	4.40445E-02	,99493	940.25	70.790	1.0000	0.00000E+00	.99493
.15	2.25800E-03	4.29757E-02	,99333	1228.2	141.05	1.0000	0.00000E+00	.99333
.19	2.22000E-03	4.19324E-02	,99177	1504.7	230.99	1.0000	0.00000E+00	,9977
.41	2.00500E-03	3.61857E-02	,98373	2959.8	338.11	1.0000	0.00000E+00	.98373
.64	1.85500E-03	3.12746E-02	.97683	4156.0	1236.9	1.0000	0.00000E+00	.97683
.86	1.72600E-03	2.70477E-02	,97090	5179.4	2397.5	1.0000	0.00000E+00	.97090
.86	1.5748	10.077	.96117	7095.4	3692.6	1.0000	0.00000E+00	.96117
1.09	1.61752E-03	2.33976E-02	,95612	4.27685E+05	6866.5	1.0000	0.00000E+00	.95612
1.31	1.51455E-03	2.02608E-02	.95177	4.28481E+05	2.43378E+07	1.0000	0.00000E+00	.95177
1.54	1.41357E-03	1.75487E-02	,94802	4.29200E+05	2.44285E+07	1.0000	0.00000E+00	.94802
1.76	1.31757E-03	1.52052E-02	.94479	4.29858E+05	2.45105E+07	1.0000	0.00000E+00	.94479
1.99	1.22157E-03	1.31747E-02	,94199	4.30466E+05	2.45857E+07	1.0000	0.00000E+00	,94199
2.21	1.12557E-03	1.14138E-02	,93957	4.31033E+05	2.46553E+07	1.0000	0.00000E+00	,93957
2.44	1.04315E-03	9.89827E-03	,93748	4.31567E+05	2.47203E+07	1.0000	0.00000E+00	.93748
2.66	9.63345E-04	8.58502E-03	,93567	4.32079E+05	2.47816E+07	1.0000	0.00000E+00	.93567
2.89	8.83545E-04	7.44358E-03	.93411	4.32576E+05	2.48404E+07	1.0000	0.00000E+00	.93411
3.11	8.09950E-04	6.45622E-03	,93275	4.33063E+05	2.48975E+07	1.0000	0.00000E+00	.93275
3.34	7.42450E-04	5.60224E-03	.93158	4.33549E+05	2.49536E+07	1.0000	0.00000E+00	.93158
3.56	6.74950E-04	4.85781E-03	,93056	4.34038E+05	2.50096E+07	1.0000	0.00000E+00	.93056
3.79	6.11916E-04	4.21214E-03	,92968	4.34530E+05	2.50661E+07	1.0000	0.00000E+00	,92968
4.01	5.70516E-04	3.66926E-03	,92891	4.35019E+05	2.51230E+07	1.0000	0.00000E+00	.92891
4.24	5.29116E-04	3.19623E-03	,92824	4.35443E+05	2.51795E+07	1.0000	0.00000E+00	.92824

```
4.46   4.87716E-04   2.78332E-03    .92766    4.35651E+05   2.52286E+07    1.0000    0.00000E+00    .92766
4.50   4.81000E-04   2.72142E-03    .92757    4.35656E+05   2.52528E+07    1.0000    0.00000E+00    .92757
VOL EXT. COEF =  1.0050E-02
VOL ABS COEF =  2.9131E-03
RASS CONC =    7283.
RASS CL =   7283.
RASS OPTICAL DEPTH =  1.0050E-02
NORM.D RANGE =   .1917
****************************************************** END OF CASE    3 *******************************************************
                              END EOSAEL RUN
STOP 000
```

5.5 Another Sample Run

Using these auxiliary data files and the third sample data file, NOVAE03.DAT, produces the sample output file NOVAE03.OUT. Here is the sample data file:

```
WAVL         10.6
VIS           7.
NOVAE
LAS1        1.000      0.0      0.0     10.0     10.0
LAS2          5.0     1.E-5     1.39    10.0      5.0
ATM1          1.0      1.0     220.     0.00   8.4E-14   -1.075      0.
ATM2          0.0   0.1220   0.0450      1.0      1.0      1.0C   3001.0
ATM3          0.0      1.0     10.0       0.
TAR1          4.5      0.0      5.0       4.       1.
TAR2          30.      30.      50.
CTRL        100.0       1.       2.       0.     20.0       0.      0.0
AVB1          0.0      2.0     0.01      1.0      0.0       I.      1.0
AVB2          0.9      1.0      .99     17.5     0.98     87.5      2.0
AVB3         1.38     0.40     0.54     1.93     408.    1.446      2.5
AVB4          2.0    3162.     0.04     0.25   0.0849  2.55E-4      98.
GO
ATM1          1.0      1.0     220.     0.00   8.4E-14   -1.075      1.
ATM3          1.0      1.0     10.0       0.
TAR1          4.5      0.0      5.0       4.       1.
TAR2           0.      30.      50.
AVB1          0.0      2.0     0.01      1.0      0.0       1.      2.0
GO
AVB1          0.0      2.0     0.01      1.0      0.0       1.      3.0
DONE
END
```

```
STOP
# THE FOLLOWING IS EOSAEL SOURCE CONTROL INFORMATION YOU CAN SAFELY REMOVE IT
# SCCS  @(#) NOVAE03.DAT 2.1 02/23/90
```

Here is the sample output file:

```
********************************************************************************
 WARNING - THIS LIBRARY CONTAINS TECHNICAL DATA YHOSE EXPORT IS RESTRICTED
 BY THE ARMS EXWRT CONTROL ACT(TITLE 22, U.S.C., SEC 2751 ET SEQ.) OR
 EXECUTIVE ORDER 12470.  VIOLATION OF THESE EXPORT LAYS ARE SUBJECT TO
               SEVERE CRIMINAL PENALTIES.
********************************************************************************
                ********************************
                *                              *
                *    ELECTRO-OPTICAL SYSTEMS   *
                *                              *
                *      ATHOSPHERIC EFFECTS     *
                *                              *
                *           LIBRARY            *
                *                              *
                * EOSAEL87 REV 2.1  02/23/90   *
                *                              *
                ********************************
WAVL          10.6
 NOTE: THAT THE ABOVE CARD VAS HODIFIED FOR CONSISTENCY TO:
WAVL      .1060E+02 .1060E+02 .0000E+00
                              BEGINNING          EWDIRC
          WAVENUHBER (CM**-1)   943.396          943.396
          WAVELENGTH (MICROMETERS) 10.600         10.600
          FREQUENCY (GHZ)      28301.885        28301.885
                            VISIBILITY
                              7.00 KM
                ********************************
                *                              *
                *         N O V A E            *
                *                              *
                *    HIGH-ENERGY LASER BEAM    *
                * ATHOSPHERIC PROPAGATION CODE *
                *    NOT FOR OPERATIONAL USE   *
                *                              *
                * EOSAEL87 REV 2.1  02/23/90   *
                *                              *
                ********************************
 ******************************** INPUT ********************************
      PARTICLE SIZE FACTOR.........    2.00
                 CONTROL PARAHETERS
                 ------------------
      WAVEFORM SPECIFIER (IDBM) ..................................   2
```

SLEU OPTION(IDSLN) 0

NUMBER OF INTEGRATION STEPS IN PHASE INTEGRAL (NPT) 20

TILT CONTROL OPTION (IDTLCO) 0

OPTIONAL INTERACTION OF LINEAR EFFECTS UITH BLOOMING (IDRSS) . 0

CONTINUOUS WAVE OR REPETITIVE WLSE OPTION (IDCWRP) 1

LASER PARAMETERS

================

LASER WAVELENGTH (WVLGTH, MICROMETERS) 10.6000

APERTURE DIAMETER (DIAM, METERS) 1.0000

BEAM PWER (POWER, KILOWATTS) .... 0.0000E+00

MAXIMUM BEAM POWER DELIVERABLE (POWMAX, KILOWATTS) ..... 0.0000E+00

ENERGY PER PULSE (ENGPUL, KILOJOULES) ....1.0000E+01

MAXIMUM ENERGY DELIVERABLE PER WLSE

(ENGMAX, KILOJOULES) ....1.0000E+01

WLSE REPETITIM RATE (PRF, SEC-1) 5.0000

PULSE DURATION TIME(TO, SECONDS) 1.000E-05

BEAM QUALITY (TIMSDL) 1.3900

ONE SIGMA HIGH FREQUENCY JITTER ANGLE

(THJH, NICRORAOIANS) 10.0000

ONE SIGMA LOU FREQUENCY JITTER ANGLE

(THJL, MICRORADIANS) 5.0000

ENVIRONMENTAL PARAMETERS

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MAGNITUDE OF UIND AT REFERENCE HEIGHT (WINDO, M/SEC) ... 1.0000

REFERENCE HEIGHT (HWINDO, METERS) 1.0000

WIND DIRECTION (ANGWND, DEGREES) 220.0000

EXPONENT IN VIND POWER LAW (WNDPOW) .... .1429

REFRACTIVE INDEX STRUCTURE CONSTANT

(CNSQO, I**(-2/31) 8.4000E-14

EXPONENT IN REFRACTIVE INDEX STRUCTURE CONSTANT

POUER LAW (CNSQPW)................................. -1.0750

CN2 PROFILE OPTION (CN2PRO) .... .0000

WIND PROFILE OPTION (WINPRO) .... .0000

QUANTITY COMBINING SEVERAL ATMOSPHERIC VARIABLES

(SCRPTS, M**3/JOULE) 1.650E-09

ABSORPTION COEFFICIENT (ABSOR, 1/KM) .... .1220

SCATTERING COEFFICIEKI (ABSSCA, 1/KM) .... .0450

SCALE HEIGHT FOR ABSORPTION COEF.(HA, KM) 1.0000

SCALE HEIGHT FOR SCATTERING COEF. (HS, KM) 1.0000

APERTURE HEIGHT ABOVE GROUND(HTDEV, METERS) 1.0000

TARGET HEIGHT ABOVE GROUND (HTTAR, METERS) 3001.0000

RANGE FROM LASER TO TARGET (RANGE, KM) 4.5000

DEFOCUSING INCREMENT(DRNGFO, KM) .... .0000

RARGE FROM TARGET TO PROJECTED IHPACT POINT (RMT, KM) .. 5.0000

X-COORDINATE OF PROJECTED IHPACT POINT (XT, KM) 4.0000

Y-COORDINATE OF PROJECTED IMPACT POINT (YT, KM) 1.0000

TRAJECTORY ANGLE(TRAJAN, DEGREES) 30.0000

BEARING OF TARGET (BEARAN, DEGREES) 30.0000
ANGULAR SLEW RATE (SLUVEL, RAD/SEC) OR SPEED OF
LASER (M/SEC) OR SPEED OF TARGET (M/SEC)
(DEPENDS ON IDSLEU OPTION) 50.0000
RADIUS OF CIRCLE FOR EXPRESSING AVERAGE INTENSITY
(RAV, CENTIMETERS) 100.0000

BREAKDOWN AND VAPORIZATION PARAMETERS

BREAKDOWN OPTION (IBRK) 0
AEROSOL TYPE (IAER) 2
PRINT OPTION(IPRTOP) 0
RANGE TO LEADING EDGE OF CLOUD (RNGA, KM) .... .90
CLOUD LENGTH (LA, METERS) 1.00
CLOUD TRANSMITTANCE (TA) .... .9900
NUMBER OF PHASE INTEGRAL STEPS IN CLOUD (NPA) 1
AIR TEMPERATURE (TATM, C) 17.5000
PRESSURE(PATM, ATM) .... .9800
RELATIVE HUMIDITY (RELH, %) 87.5000
REAL PART OF REFRACTIVE INDEX (NR) 1.3800
IMAGINARY PART OF REFRACTIVE INDEX (NI) .... .4000
MEDIAN HASS RADIUS OF SIZE DISTRIBUTION
(RM, MICROMETERS) .... .5400
STANDARD DEVIATION OF SIZE DISTRIBUTION (SIG) 1.9300
BOILING TEMPERATURE (TBOIL. K) 408.0000
BULK MATERIAL DENSITY (RDA, G/CM**3) 1.4460
BULK MATERIAL SPECIFIC HEAT (CPA, J/G K) 2.5000
VAPOR SPECIFIC HEAT (CPV, J/G K) 2.0000
HEAT OF VAPORIZATION(LHA, J/G) 3162.00
EVAPORATION COEFFICIENT (EPSA) .... .0400
VAPOR DIFFUSION COEFFICIENT(DCA, CM**2/SEC) .... .2500
VAPOR GAS CONSTANT (RGA, JIG K) .... .0849
AIR THERHAL CONDUCTIVITY (KAIR, W/CM K) 2.550E-04
VAPOR MOLECULAR VEIGHT (MV, G/MOLE) 98.0000
RECONDENSATION OPTION (IRECON) 0
EXPONENTIAL AEROSOL SCALING OPTION (EXEXSC) 1
EXACT HIE EFFICIENCY FACTOR OPTION (DATAP) 1

BEAM TYPE IS REPETITIVE PULSE
CALCULATION DOES NOT INCLUDE SRS
BEAM PROFILE IS TRUNCATED GAUSSIAN
AEROSOL TYPE IS WP/RP SMOKE
NO TILT CONTROL (BEAM WANDER INCLUDED)
LINEAR EFFECTS INCLUDED BEFORE BLOOMING CALCULATIONS
DO NOT CHECK FOR BREAKDOWN
EXPONENTIAL AEROSOL EXTINCTION SCALING ASSUHED IN VAPORIZATION MODEL
DATA FILE VITH EXACT HIE EFFICINCY FACTORS USED
NEGLIGIBLE RECONDENSATION ASSUMED BETVEEN PULSES
EPS = .9715 ROEV = 1.0955E-02 CND = .7843

DFF = 9.9404E-02 NONEQ = 5.8576E-02 EQUIL = 1.014

DEFAULT VALUES FOR UATER: 2.1818, ,0722, .83, ,5875, 2.139, 1.569

Z (M)	PEAK (KW/CM**2)	AVG (KW/CM**2)	AREA (CM**2)
.0000	1.472124E-02	9.305597E-03	3.396454E+03
37.5000	1.485770E-02	9.391856E-03	3.344767E+03
75.0000	1.500682E-02	9.486118E-03	3.291862E+03
112.5000	1.516191E-02	9.584159E-03	3.239313E+03
150.0000	1.532278E-02	9.685847E-03	3.187193E+03
187.5000	1.548954E-02	9.791255E-03	3.135505E+03
412.5000	1.665224E-02	1.052622E-02	2.834510E+03
637.5000	1.808183E-02	1.142990E-02	2.547063E+03
862.5000	1.985202E-02	1.254887E-02	2.271406E+03

CA (G/CM**3) = 7.1199E-08

CNT = 7132.

SUMPD = 73.19

TOTAL 10. DENSITY (#/CM**3) = 5.2197E+05

RMODE = 9.5798E-02

TAW = 2.3753E-06

TP(RP) OR TFLOW(CW)/TAUW = 4.210

863.5000	1.976717E-02	1.249523E-02	2.270279E+03
1088.5000	2.177628E-02	1.376523E-02	2.023680E+03
1313.5000	2.441352E-02	1.543229E-02	1.777039E+03
1538.5000	2.764162E-02	1.747284E-02	1.548505E+03
1763.5000	3.161960E-02	1.998740E-02	1.338085E+03
1988.5000	3.655965E-02	2.311011E-02	1.145786E+03
2213.5000	4.274428E-02	2.701954E-02	9.716202E+02
2438.5000	5.054565E-02	3.195095E-02	8.156043E+02
2663.5000	6.043984E-02	3.820527E-02	6.777603E+02
2888.5000	7.299501E-02	4.614165E-02	5.581197E+02
3113.5000	8.878001E-02	5.611967E-02	4.567282E+02
3338.5000	1.080797E-01	6.831941E-02	3.736513E+02
3563.5000	1.302445E-01	8.233025E-02	3.089828E+02
3788.5000	1.526445E-01	9.648973E-02	2.628495E+02
4013.5000	1.700013E-01	1.074613E-01	2.354032E+02
4238.5000	1.760692E-01	1.112969E-01	2.267849E+02
4463.5000	1.681128E-01	1.062675E-01	2.370632E+02
4500.0000	1.656529E-01	1.047126E-01	2.405106E+02

** OUTPUT **

RP OPTION

KEY: DL = DIFFRACTION-LIMITED T = TURBULENCE J = JITTER B = BLOOMING O = OPTIMUM POWER

	DL	TJ	8	BTJ	0	BTJO
RADIUS OF EXP(-1) BEAM (CM)	4.314E+00	8.355E+00	4.796E+00	8.750E+00	4.796E+00	8.750E+00
AREA OF EXP(-1) BEAM (CM**2)	5.848E+01	2.193E+02	7.226E+01	2.405E+02	7.226E+01	2.405E+02
TIME AVERAGE OF SPATIAL PEAK INTENSITY (KW/CM**2)	6.813E-01	1.817E-01	5.513E-01	1.657E-01	5.513E-01	1.657E-01

TIME AVERAGE OF SPATIAL AVERAGE INTEWSIN OVER CIRCLE Of EXP(-1) RADIUS (KW/CM**2)	4.306E-01	1.148E-01	3.485E-01	1.047E-01	3.485E-01	1.047E-01
TIME AVERAGE OF SPATIAL AVERAGE INTENSITY OVER CIRCLE OF SPECIFIED RADIUS RAV (KW/CM**2)	1.268E-03	1.268E-03	1.268E-03	1.268E-03	1.268E-03	1.268E-03
FLUENCE (KJ/CM**2)	1.363E-01	3.633E-02	1.103E-01	3.313E-02	1.103E-01	3.313E-02
PEAK INTENSITY PER PULSE (MW/CM**2)	1.363E+01	3.633E+00	1.103E+01	3.313E+00	1.103E+01	3.313E+00
OPTIMUM ENERGY PER PULSE (KJOULE)					1.000E+01	1.000E+01

FRACTION OF INITIAL WUER PROPAGATED TO RAKE OF IWTEREST = 7.9683E-01

PHICON = 1.6875E+06

ZETI (KM)	ALPABS (1/KM)	ALPEXT (1/KM)	BZETA	XB	HBZ	SFBD	ALPBD (1/KM)	BZETAB
.00	,12200	,16700	1.0000	0.00000E+00	1.0000	1.0000	0.00000E+00	1.0000
.04	.11899	.16288	.99391	.33513	1.0000	1.0000	0.00000E+00	.99391
.08	.11605	,15886	.98801	.54995	1.0109	1.0000	0.00000E+00	.98801
.11	,11318	.15493	.98228	,75671	1.0182	1.0000	0.00000E+00	.98228
.15	.11039	,15111	,97673	.96063	1.0254	1.0000	0.00000E+00	.97673
.19	.10766	,14738	,97135	1.1618	1.0329	1.0000	0.00000E+00	.97135
.41	9.26678E-02	.12685	94402	2.3160	1.0404	1.0000	0.00000E+00	.94402
64	7.97599E-02	.10918	.92111	3.2126	1.0884	1.0000	0.00000E+00	.92111
.86	6.86500E-02	9.39717E-02	.90184	3.6862	1.1311	1.0000	0.00000E+00	.90184
.86	.72877	4.7797	89754	3.6929	1.1556	1.0000	0.00000E+00	.89754
1.09	5.90482E-02	8.08283E-02	.88136	5.0892	1.1559	1.0000	0.00000E+00	.88136
1.31	5.08233E-02	6.95696E-02	,86768	5.0892	1.2357	1.0000	0.00000E+00	.86768
1.54	4.37440E-02	5.98791E-02	.85606	5.0892	1.2357	1.0000	0.00000E+00	.85606
1.76	3.76508E-02	5.15384E-02	,84619	5.0892	1.2357	1.0000	0.00000E+00	.84619
1.99	3.24063E-02	4.43595E-02	.83779	5.0892	1.2357	1.0000	0.00000E+00	.83779
2.21	2.7892B-02	3.81806E-02	.83062	5.0892	1.2357	1.0000	0.00000E+00	.83062
2.44	2.40072E-02	3.28623E-02	,82451	5.0892	1.2357	1.0000	0.00000E+00	.82451
2.66	2.06632E-02	2.82849E-02	.81927	5.0892	1.2357	1.0000	0.00000E+00	.81927
2.89	1.77850E-02	2.43450E-02	.81480	5.0892	1.2357	1.0000	0.00000E+00	.81480
3.11	1.53077E-02	2.09539E-02	.81097	5.0892	1.2357	1.0000	0.00000E+00	.81097
3.34	1.31754E-02	1.80352E-02	,80768	5.0892	1.2357	1.0000	0.00000E+00	.80768
3.56	1.13402E-02	1.55231E-02	,80487	5.0892	1.2357	1.0000	0.00000E+00	.80487
3.79	9.76060E-03	1.33608E-02	.80245	5.0892	1.2357	1.0000	0.00000E+00	.80245
4.01	8.40103E-03	1.14998E-02	.80038	5.0892	1.2357	1.0000	0.00000E+00	.80038
4.24	7.23083E-03	9.89795E-03	,79860	5.0892	1.2357	1.0000	0.00000E+00	.79860
4.46	6.22364E-03	8.51924E-03	,79707	5.0892	1.2357	1.0000	0.00000E+00	.79707
4.50	6.07402E-03	8.31444E-03	.79683	5.0892	1.2357	1.0000	0.00000E+00	.79683

VOL EXT. COEF = 4.6858E-03

VOL ABS COEF = 4.1392E-03

MASS CONC = 7.1199E-02

MASS CL = 7.1199E-02

MASS OPTICAL DEPTH = 1.0050E-02

NORM.D RANGE = .1917

** END OF CASE 1 **

****************************** INPUT ******************************

PARTICLE SIZE FACTOR.......... 2.00

CONTROL PARAMETERS

WAVEFORM SPECIFIER (IDBM) 2
SLEW OPTION (IDSLEW) 0
NUMBER OF INTECRATION STEPS IN PHASE INTEGRAL (NPT) 20
TILT CONTROL OPTION (IDTLCO) 0
OPTIONAL INTERACTION OF LINEAR EFFECTS WITH BLOOMING (IDRSS) . 0
CONTINUOUS VAVE OR REPETITIVE PULSE OPTION (IDCWRP) 1

LASER PARAMETERS

LASER WAVELENGTH (WVLGTH, MICROMETERS) 10.6000
APERNRE DIAMETER (DIAM, METERS) 1.0000
BEAN POUER (POWER, KILOWATTS) .... 0.000E+00
MAXIMUM BEAN POWER DELIVERABLE (POWMAX, KILOVATIS) ..... 0.000E+00
ENERGY PER PULSE (ENGPUL, KILOJWLES) ....1.0000E+01
MAXIMUM ENERGY DELIVERABLE PER PULSE
(ENGMAX, KILOJOULES) ....1.0000E+01
WLSE REPETITION RATE (PRF, SEC-1) 5.0000
PULSE DURATION TIME(TO, SECONDS) 1.000E-05
BEAM QUALITY (TIMSDL) 1.3900
ONE SIGMA HIGH FREQUENCY JITTER ANGLE
(THJH, MICRORADIANS) 10.0000
ONE SIGMA LOW FREQUENCY JITTER ANGLE
(THJL, MICRORADIANS) 5.0000

ENVIRONMENTAL PARAMETERS

MAGNITUDE OF WIND AT REFERENCE HEIGHT (WINDO, M/SEC) ... 1.0000
REFERENCE HEIGHT (HWINDO, METERS) 1.0000
WIND DIRECTION(ANCVND, DEGREES) 220.0000
EXPONENT IN WIND POWER LAW (WNDPOW) .... .1429
REFRACTIVE INDEX STRUCTURE CONSTANT
(CNSQ0, M**(-2/3)) 8.400E-14
EXPONENT IN REFRACTIVE INDEX STRUCTURE CONSTANT
POWER LAV (CNSQPW).................................... -1.0750
CN2 PROFILE OPTION (CN2PRO) 1.0000
WIND PROFILE OPTION (WINPRO) .... .0000
QUANTITY COMBINING SEVERAL ATMOSPHERIC VARIABLES
(SCRPTS, M**3/JOULE) 1.650E-09
ABSORPTION COEFFICIENT(ABSOR, 1/KM) .... .1220
SCATTERING COEFFICIENT(ABSSCA, 1/KM) .... .0450
SCALE HEIGHT FOR ABSORPTION COEF.(HA, KM) 1.0000
SCALE HEIGHT FOR SCATTERING COEF.(HS, KM) 1.0000
APERTURE HEIGHT ABOVE GROUND(HTDEV, METERS) 1.0000

TARGET HEIGHT ABOVE GROUND (HTTAR, METERS) 3001.0000

RANGE FROM LASER TO TARGET (RANGE, KM) 4.5000

DEFOCUSING INCREMENT (DRNGFO, KM) .... .0000

RANGE FROM TARGET TO PROJECTED IMPACT POINT (RMT, KM) .. 5.0000

X-COORDINATE OF PROJECTED IMPACT POINT (XT, KM) 4.0000

Y-COORDINATE OF PROJECTED IMPACT POINT (YT, KM) 1.0000

TRAJECTORY ANGLE (TRAJAN, DEGREES) .... .0000

BEARING OF TARGET (BEARAN, DEGREES) 30.0000

ANGULAR SLEW RATE (SLUVEL, RAD/SEC) OR SPEED OF
LASER (M/SEC) OR SPEED OF TARGET (M/SEC)
(DEPENDS ON IDSLEW OPTION) 50.0000

RADIUS OF CIRCLE FOR EXPRESSING AVERAGE INTENSITY
(RAV, CENTIMETERS) 100.0000

BREAKDOWN AND VAPORIZATION PARAMETERS

BREAKDOWN OPTION (IBRK) 0

AEROSOL TYPE (IAER) 2

PRINT OPTION (IPRTOP) 0

RANGE TO LEADING EDGE OF CLOUD (RNGA, KM) .... .90

CLOUD LENGTH (LA, METERS) 1.00

CLOUD TRANSMITTANCE (TA) .... .9900

NUMBER OF PHASE INTEGRAL STEPS IN CLOUD (NPA) 1

AIR TEMPERATURE (TATM, C) 17.5000

PRESSURE (PATM, ATM) .... .9800

RELATIVE HUMIDITY (RELH, %) 87.5000

REAL PART OF REFRACTIVE INDEX (MR) 1.3800

IMAGINARY PART OF REFRACTIVE INDEX (MI) .... .4000

MEDIAN MASS RADIUS OF SIZE DISTRIBUTION
(RM, MICROMETERS) .... .5400

STANDARD DEVIATION OF SIZE DISTRIBUTION (SIG) 1.9300

BOILING TEMPERATURE (TBOIL, K) 408.0000

BULK MATERIAL DENSITY (RHOA, G/CM**3) 1.4460

BULK MATERIAL SPECIFIC HEAT (CPA, J/G K) 2.5000

VAPOR SPECIFIC HEAT (CPV, J/G K) 2.0000

HEAT OF VAPORIZATION (LHA, J/G) 3162.00

EVAPORATION COEFFICIENT (EPSA) .... .0400

VAPOR DIFFUSION COEFFICIENT (DCA, CM**2/SEC) .... .2500

VAPOR GAS CONSTANT (RGA, J/G K) .... .0849

AIR THERMAL CONDUCTIVITY (KAIR, W/CM K) 2.550E-04

VAPOR MOLECULAR WEIGHT (MV, G/MOLE) 98.0000

RECONDENSATION OPTION (IRECON) 0

EXPONENTIAL AEROSOL SCALING OPTION (EXEXSC) 1

EXACT MIE EFFICIENCY FACTOR OPTION (DATAP) 2

BEAM TYPE IS REPETITIVE PULSE

CALCULATION DOES INCLUDE SRS

DOES NOT INCLUDE BREAKDOWN AND EXTINCTION ATTENUATION IN ENERGY OR POWER PASSED TO SRS ROUTINE

SRS CALCULATION IS VIBRATIONAL

BEAM PROFILE IS TRUNCATED GAUSSIAN

AEROSOL TYPE IS WP/RP SMOKE

NO TILT CONTROL (BEAM UANDER INCLUDED)

LINEAR EFFECTS INCLUDED BEFORE BLOOMING CALCULATIONS

DO NOT CHECK FOR BREAKDOWN

EXPONENTIAL AEROSOL EXTINCTION SCALING ASSUMED IN VAPORIZATION MODEL

APPROXIMATE MIE EFFICIENCY FACTORS USED

NEGLIGIBLE RECONDENSATION ASSUMED BETWEEN WLSES

EPS = .9715 RON = 1.0955E-02 CND = .7843

DIF = 9.9404E-02 NONEQ = 5.8576E-02 EQUIL = 1.014

DEFAULT VALUES FOR WATER: 2.1818, ,0722, .83, .5875, 2.139, 1.569

Z	PEAK	AVG	AREA
(M)	(KW/CM**2)	(KW/CM**2)	(CM**2)
.0000	1.472124E-02	9.305597E-03	3.396454E+03
37.5000	1.485770E-02	9.391856E-03	3.344767E+03
75.0000	1.500681E-02	9.486115E-03	3.291864E+03
112.5000	1.516196-02	9.584148E-03	3.239317E+03
150.0000	1.532275E-02	9.685828E-03	3.187199E+03
187.5000	1.548949E-02	9.791224E-03	3.135515E+03
412.5000	1.665192E-02	1.052602E-02	2.834564E+03
637.5000	1.808087E-02	1.142929E-02	2.547198E+03
862.5000	1.984979E-02	1.254746E-02	2.271662E+03

CA (G/CM**3) = 3.7272E-08

CNT = 3734.

SUMPD = 73.19

TOTAL NO. DENSITY (#/CM**3) = 2.7324E+05

RMODE = 9.5798E-02

TAW = 2.3753E-06

TP(RP) OR TFLOW(CW)/TAUV = 4.210

863.5000	1.979830E-02	1.251492E-02	2.270499E+03
1088.5000	2.189732E-02	1.384175E-02	2.015858E+03
1313.5000	2.455317E-02	1.552057E-02	1.769886E+03
1538.5000	2.780347E-02	1.757515E-02	1.542065E+03
1763.5000	3.180753-02	2.010620E-02	1.332403E+03
1988.5000	3.677735E-02	2.324772E-02	1.140907E+03
2213.5000	4.299405E-02	2.717742E-02	9.675908E+02
2438.5000	5.082569E-02	3.212797E-02	8.124667E+02
2663.5000	6.073848E-02	3.839405E-02	6.755555E+02
2888.5000	7.327914E-02	4.632126E-02	5.568853E+02
3113.5000	8.897369E-02	5.624210E-02	4.564960E+02
3338.5000	1.080309E-01	6.828856E-02	3.744452E+02
3563.5000	1.296934E-01	8.198187E-02	3.108147E+02
3788.5000	1.512510E-01	9.560888E-02	2.657147E+02
4013.5000	1.675290E-01	1.058986E-01	2.392764E+02
4238.5000	1.726811E-01	1.091553E-01	2.316211E+02
4463.5000	1.644102E-01	1.039271E-01	2.428072E+02

NO RAHAN CONVERSION Z = 4.50E+03

4500.0000 1.619659E-01 1.023820E-01 2.463967E+02

** OUTPUT **

RP OPTION

KEY: DL = DIFFRACTION-LIMITED T = NRBULENCE J = JITTER B = BLOOHNG O = OPTIMUM POYER

	DL	+ TJ	+ B	+ BTJ	+ O	+ BTJO
RADIUS OF EXP(-1) BEAM (CM)	4.314E+00	8.527E+00	4.719E+00	8.856E+00	4.719E+00	8.856E+00
AREA OF EXP(-1) BEAM (CM**2)	5.848E+01	2.284E+02	6.996E+01	2.464E+02	6.996E+01	2.464E+02
TIME AVERAGE OF SPATIAL PEAK INTENSITY (KW/CM**2)	6.82kE-01	1.747E-01	5.704E-01	1.620E-01	5.704E-01	1.620E-01
TIME AVERAGE OF SPATIAL AVERAGE INTENSITY OVER CIRCLE OF EXP(-1) RADIUS (KW/CM**2)	4.314E-01	1.104E-01	3.606E-01	1.024E-01	3.606E-01	1.024E-01
TIME AVERAGE OF SPATIAL AVERAGE INTENSITY OVER CIRCLE OF SPECIFIED RADIUS RAV (KW/CM**2)	1.270E-03	1.270E-03	1.270E-03	1.270E-03	1.270E-03	1.270E-03
FLUENCE (KJ/CM**2)	1.365E-01	3.494E-02	1.141E-01	3.239E-02	1.141E-01	3.239E-02
PEAK INTENSITY PER PULSE (MW/CM**2)	1.365E+01	3.494E+00	1.141E+01	3.239E+00	1.141E+01	3.239E+00
OPTIMUM ENERGY PER PULSE (KJOULE)					1.000E+01	1.000E+01

FRACTION OF INITIAL POYER PROPAGATED TO RANGE OF INTEREST = 7.9816E-01

PHICOR = 1.6875E+06

ZETI (KM)	ALPABS (1/KM)	ALPEXT (1/KM)	BZETA	XB	HBZ	SFBD	ALPBD (1/KM)	BZETAB
.OO	,12200	,16700	1.0000	0.00000E+00	1.0000	1.0000	0.00000E+00	1.0000
.04	,11899	16288	.99391	,33513	1.0000	1.0000	0.00000E+00	.99391
.08	.11605	15886	,98801	.54995	1.0109	1.0000	0.00000E+00	.98801
.11	.11318	,15493	.98228	,75671	1.0182	1.0000	0.00000E+00	.98228
.15	,11039	.15111	97673	.96063	1.0254	1.0000	0.00000E+00	.97673
.19	,10766	,14738	,97135	1.1618	1.0329	1.0000	0.00000E+00	,97135
.41	9.26678E-02	,12685	,94402	2.3160	1.0404	1.0000	0.00000E+00	,94402
.64	7.97599E-02	.10918	.92111	3.2126	1.0884	1.0000	0.00000E+00	,92111
.86	6.86500E-02	9.39717E-02	,90184	3.6862	1.1311	1.0000	0.00000E+00	.90184
.86	,38346	3.1091	.89904	3.6900	1.1556	1.0000	0.00000E+00	.89904
1.09	5.90482E-02	8.08283E-02	,88284	4.4260	1.1558	1.0000	0.00000E+00	.88284
1.31	5.08233E-02	6.95696E-02	,86913	4.4260	1.1964	1.0000	0.00000E+00	.86913
1.54	4.37440E-02	5.98791E-02	,85750	4.4260	1.1964	1.0000	0.00000E+00	.85750
1.76	3.76508E-02	5.15384E-02	,84761	4.4260	1.1964	1.0000	0.00000E+00	.84761
1.99	3.24063E-02	4.43595E-02	,83919	4.4260	1.1964	1.0000	0.00000E+00	.83919
2.21	2.78924E-02	3.81806E-02	,83201	4.4260	1.1964	1.0000	0.00000E+00	.83201
2.44	2.40072E-02	3.28623E-02	,82588	4.4260	1.1964	1.0000	0.00000E+00	.82588
2.66	2.06632E-02	2.82849E-02	,82064	4.4260	1.1964	1.0000	0.00000E+00	.82064
2.89	1.77850E-02	2.43450E-02	.81616	4.4260	1.1964	1.0000	0.00000E+00	.81616
3.11	1.53077E-02	2.09539E-02	,81232	4.4260	1.1964	1.0000	0.00000E+00	.81232
3.34	1.31754E-02	1.80352E-02	,80903	4.4260	1.1964	1.0000	0.00000E+00	,80903
3.56	1.13402E-02	1.55231E-02	.80621	4.4260	1.1964	1.0000	0.00000E+00	,80621

3.79	9.76060E-03	1.33608E-02	.80379	4.4260	1.1964	1.0000	0.00000E+00	.80379
4.01	8.40103E-03	1.14998E-02	.80172	4.4260	1.1964	1.0000	0.00000E+00	.80172
4.24	7.23083E-03	9.89795E-03	.79993	4.4260	1.1964	1.0000	0.00000E+00	.79993
4.46	6.22364E-03	8.51924E-03	.79840	4.4260	1.1964	1.0000	0.00000E+00	.79840
4.50	6.07402E-03	8.31444E-03	.79816	4.4260	1.1964	1.0000	0.00000E+00	.79816

VOL EXT. COEF = 3.0152E-03

VOL ABS COEF = 2.9750E-03

MASS CONC = 3.7272E-02

MASS CL = 3.7272E-02

MASS OPTICAL DEPTH = 1.0050E-02

NORM.D RANGE = .1917

** END OF CASE 2 **

********************************** INPUT **********************************

PARTICLE SIZE FACTOR......... 2.00

CONTROL PARAMETERS

WAVEFORM SPECIFIER (IDBM) 2

SLEW OPTION (IDSLEW) 0

NUMBER OF INTEGRATION STEPS IN PHASE INTEGRAL (NPT) 20

TILT CONTROL OPTION (IDTLCO) 0

OPTIONAL INTERACTION OF LINEAR EFFECTS WITH BLOOMING (IDRSS) . 0

CONTINUOUS WAVE OR REPETITIVE PULSE OPTION (IDCWRP) 1

LASER PARAMETERS

LASER WAVELENGTH (WVLGTH, MICROMETERS) 10.6000

APERTURE DIAMETER (DIAM, METERS) 1.0000

BEAM POWER (POWER, KILOWATTS) .... 0.000E+00

MAXIMUM BEAM POWER DELIVERABLE (POWMAX, KILOWATTS) ..... 0.000E+00

ENERGY PER PULSE (ENGPUL, KILOJOULES) ....1.0000E+01

MAXIMUM ENERGY DELIVERABLE PER PULSE

(ENGMAX, KILOJOULES) ....1.0000E+01

PULSE REPETITION RATE (PRF, SEC-1) 5.0000

PULSE DURATION TIME (TO, SECONDS) 1.000E-05

BEAM QUALITY (TIMSDL) 1.3900

ONE SIGMA HIGH FREQUENCY JITTER ANGLE

(THJH, MICRORADIANS) 10.0000

ONE SIGMA LOW FREQUENCY JITTER ANGLE

(THJL, MICRORADIANS) 5.0000

ENVIROMENTAL PARAMETERS

MAGNITUDE OF WIND AT REFERENCE HEIGHT (UINDO, M/SEC) ... 1.0000

REFERENCE HEIGHT (HWINDO, METERS) 1.0000

WIND DIRECTION (ANGWND, DEGREES) 220.0000

EXPONENT IN WIND POWER LAW (WNDPOW) .... .1429

REFRACTIVE INDEX STRUCTURE CONSTANT

(CNSQO, M**(-2/3)) 8.400E-14

EXPONENT IN REFRACTIVE INDEX STRUCTURE CONSTANT

POWER LAW (CNSQPW)	-1.0750
CN2 PROFILE OPTION (CN2PRO)	1.0000
WIND PROFILE OPTION (WINPRO)	.0000
QUANTITY COMBINING SEVERAL ATMOSPHERIC VARIABLES (SCRPTS, M**3/JOULE)	1.650E-09
ABSORPTION COEFFICIENT (ABSOR, 1/KM)	.1220
SCATTERING COEFFICIENT (ABSSCA, 1/KM)	.0450
SCALE HEIGHT FOR ABSORPTION COEF. (HA, KM)	1.0000
SCALE HEIGHT FOR SCATTERING COEF. (HS, KM)	1.0000
APERTURE HEIGHT ABOVE GROUND (HTDEV, METERS)	1.0000
TARGET HEIGHT ABOVE GROUND (HTTAR, METERS)	3001.0000
RANGE FROM LASER TO TARGET (RANGE, KM)	4.5000
DEFOCUSING INCREMENT (DRNGFO, KM)	.0000
RANGE FROM TARGET TO PROJECTED IMPACT POINT (RNT, KM)	5.0000
X-COORDINATE OF PROJECTED IMPACT POINT (XT, KM)	4.0000
Y-COORDINATE OF PROJECTED IMPACT POINT (YT, KM)	1.0000
TRAJECTORY ANGLE (TRAJAN, DEGREES)	.0000
BEARING OF TARGET (BEARAN, DEGREES)	30.0000
ANGULAR SLEW RATE (SLUVEL, RAD/SEC) OR SPEED OF LASER (M/SEC) OR SPEED OF TARGET (M/SEC) (DEPENDS ON IDSLEW OPTION)	50.0000
RADIUS OF CIRCLE FOR EXPRESSING AVERAGE INTENSITY (RAV, CENTIMETERS)	100.0000

BREAKDOWN AND VAPORIZATION PARAMETERS

BREAKDOWN OPTION (IBRK)	0
AEROSOL TYPE (IAER)	2
PRINT OPTION (IPRTOP)	0
RANGE TO LEADING EDGE OF CLOUD (RNGA, KM)	.90
CLOUD LENGTH (LA, METERS)	1.00
CLOUD TRANSMITTANCE (TA)	.9900
NUMBER OF PHASE INTEGRAL STEPS IN CLOUD (NPA)	1
AIR TEMPERATURE (TATM, C)	17.5000
PRESSURE (PATM, ATM)	.9800
RELATIVE HUMIDITY (RELH, %)	87.5000
REAL PART OF REFRACTIVE INDEX (NR)	1.3800
IMAGINARY PART OF REFRACTIVE INDEX (NI)	.4000
MEDIAN MASS RADIUS OF SIZE DISTRIBUTION (RM, MICROMETERS)	.5400
STANDARD DEVIATION OF SIZE DISTRIBUTION (SIG)	1.9300
BOILING TEMPERATURE (TBOIL, K)	408.0000
BULK MATERIAL DENSITY (ROA, G/CM**3)	1.4460
BULK MATERIAL SPECIFIC HEAT (CPA, J/G K)	2.5000
VAPOR SPECIFIC HEAT (CPV, J/G K)	2.0000
HEAT OF VAPORIZATION (LHA, J/G)	3162.00
EVAPORATION COEFFICIENT (EPSA)	.0400
VAPOR DIFFUSION COEFFICIENT (DCA, CM**2/SEC)	.2500

VAPOR GAS CONSTANT(RGA, J/G K) .... .0849

AIR THERMAL CONDUCTIVITY (KAIR, W/CM K) 2.550E-04

VAPOR MOLECULAR YEIGHT (MV, G/MOLE) 98.0000

RECONDENSATION OPTION (IRECON) 0

EXPONENTIAL AEROSOL SCALING OPTION (EXEXSC) 1

EXACT MIE EFFICIENCY FACTOR OPTION (DATAP) 3

BEAI TYPE IS REPETITIVE PULSE

CALCULATION DOES INCLUDE SRS

DOES NOT INCLUDE BREAKDOWN AND EXTINCTION ATTENUATION IN ENERGY OR POWER PASSED TO SRS ROUTINE

SRS CALCULATION IS VIBRATIONAL

BEAM PROFILE IS TRUNCATED GAUSSIAN

AEROSOL TYPE IS WP/RP SMOKE

NO TILT CONTROL (BEAM WANDER INCLUDED)

LINEAR EFFECTS INCLUDED BEFORE BLOOMING CALCULATIONS

DO NOT CHECK FOR BREAKDOWN

EXPONENTIAL AEROSOL EXTINCTION SCALING ASSUMED IN VAPORIZATION MODEL

CALL ACAUS TO CALCULATE MIE EFFICIENCY FACTORS.

NEGLIGIBLE RECORDENSATION ASSUMED BETWEEN PULSES

NOVAE VARNING: FILE(AG.OUT)

WILL BE OVER YRITTEN

EPS : .9715 ROEV : 1.0955E-02 CND : .7843

DFF : 9.9404E-02 NONEQ : 5.8576E-02 EQUIL : 1.014

DEFAULT VALUES FOR YATER: 2.1818, .0722, .83, .5875, 2.139, 1.569

Z	PEAK	AVG	AREA
(M)	(KW/CM**2)	(KW/CM**2)	(CM**2)
.0000	1.472124E-02	9.305597E-03	3.396454E+03
37.5000	1.485770E-02	9.391856E-03	3.344767E+03
75.0000	1.500681E-02	9.486115E-03	3.291864E+03
112.5000	1.516190E-02	9.584148E-03	3.239317E+03
150.0000	1.532275E-02	9.685828E-03	3.187199E+03
187.5000	1.548949E-02	9.791224E-03	3.135515E+03
412.5000	1.665192E-02	1.052602E-02	2.834564E+03
637.5000	1.808087E-02	1.142929E-02	2.547198E+03
862.5000	1.984979E-02	1.254746E-02	2.271662E+03

CA (G/CM**3) : 7.3264E-08

CNT : 7339.

SUMPD : 73.19

TOTAL NO. DENSITY (#/CM**3) : 5.3711E+05

RMODE : 9.5798E-02

TAW : 2.3753E-06

TP(RP) OR TFLOW(CW)/TAUV : 4.210

863.5000	1.976482E-02	1.249375E-02	2.270539E+03
1088.5000	2.176232E-02	1.375641E-02	2.024969E+03
1313.5000	2.439350E-02	1.541963E-02	1.778490E+03
1538.5000	2.761189E-02	1.745404E-02	1.550167E+03
1763.5000	3.157412E-02	1.995865E-02	1.340007E+03
1988.5000	3.648835E-02	2.306504E-02	1.148020E+03

2213.5000	4.263004E-02	2.694733E-02	9.742200E+02
2438.5000	5.035909E-02	3.183302E-02	8.186225E+02
2663.5000	6.012987E-02	3.800933E-02	6.812515E+02
2888.5000	7.247276E-02	4.581152E-02	5.621393E+02
3113.5000	8.789352E-02	5.555930E-02	4.613329E+02
3338.5000	1.065823E-01	6.737287E-02	3.788993E+02
3563.5000	1.277830E-01	8.077425E-02	3.149337E+02
3788.5000	1.488412E-01	9.408561E-02	2.695648E+02
4013.5000	1.647226E-01	1.041246E-01	2.429459E+02
4238.5000	1.697558E-01	1.073061E-01	2.352182E+02
4463.5000	1.617090E-01	1.022196E-01	2.464500E+02

NO RAMAN CONVERSION Z = 4.50E+03

4500.0000	1.593275E-01	1.007142E-01	2.500579E+02

** OUTPUT **

RP OPTION

KEY: DL = DIFFRACTION-LIMITED T = TURBULENCE J = JITTER B = BLOOMING O = OPTIMUM POWER

	DL	+ TJ	+ B	+ BTJ	+ O	+ BTJO
RADIUS OF EXP(-1) BEAM (CM)	4.314E+00	8.527E+00	4.804E+00	8.922E+00	4.804E+00	8.922E+00
AREA OF EXP(-1) BEAM (CM**2)	5.848E+01	2.284E+02	7.251E+01	2.501E+02	7.251E+01	2.501E+02
TIME AVERAGE OF SPATIAL PEAK INTENSITY (KW/CM**2)	6.813E-01	1.744E-01	5.494E-01	1.593E-01	5.494E-01	1.593E-01
TIME AVERAGE OF SPATIAL AVERAGE INTENSITY OVER CIRCLE OF EXP(-1) RADIUS (KY/CM**2)	4.306E-01	1.103E-01	3.473E-01	1.007E-01	3.473E-01	1.007E-01
TIME AVERAGE OF SPATIAL AVERAGE INTENSITY OVER CIRCLE OF SPECIFIED RADIUS RAV (KW/CM**2)	1.268E-03	1.268E-03	1.268E-03	1.268E-03	1.268E-03	1.268E-03
FLUENCE (KJ/CM**2)	1 363E-01	3.488E-02	1.099E-01	3.187E-02	1.099E-01	3.187E-02
PEAK IHTENSITY PER PULSE (MW/CM**2)	1.363E+01	3.488E+00	1.099E+01	3.187E+00	1.099E+01	3.187E+00
OPTIMUM ENERGY PER PULSE (KJOULE)					1.000E+01	1 000E+01

FRACTION OF INITIAL POWER PROPAGATED TO RANGE OF INTEREST = 7.9682E-01

PHICON = 1.6875E+06

ZETI (KM)	ALPABS (1/KM)	ALPEXT (1/KM)	BZETA	X8	HBZ	SFBD	ALPBD (1/KM)	BZETAB
.00	.12200	.16700	1.0000	0.00000E+00	1.0000	1.0000	0.00000E+00	1.0000
.04	.11899	.16288	.99391	.33513	1.0000	1.0000	0.00000E+00	.99391
.08	.11605	.15886	.98801	.54995	1.0109	1.0000	0.00000E+00	.98801
.11	.11318	.15493	.98228	.75671	1.0182	1.0000	0.00000E+00	.98228
.15	.11039	.15111	.97673	.96063	1.0254	1.0000	0.00000E+00	.97673
.19	.10766	.14738	.97135	1.1618	1.0329	1.0000	0.00000E+00	.97135
.41	9.26678E-02	.12685	.94402	2.3160	1.0404	1.0000	0.00000E+00	.94402
.64	7.97590E-02	.10918	.92111	3.2126	1.0884	1.0000	0.00000E+00	.92111
.86	6.86500E-02	9.39717E-02	.90184	3.6862	1.1311	1.0000	0.00000E+00	.90184
.86	.76469	4.7838	.89754	3.6932	1.1556	1.0000	0.00000E+00	.89754

1.09	5.90482E-02	8.08283E-02	.88136	5.1583	1.1559	1.0000	0.00000E+00	.88136
1.31	5.08233E-02	6.95696E-02	,86767	5.1583	1.2399	1.0000	0.00000E+00	.86767
1.54	4.37440E-02	5.98791E-02	.85606	5.1583	1.2399	1.0000	0.00000E+00	.85606
1.76	3.76508E-02	5.15384E-02	.84619	5.1583	1.2399	1.0000	0.00000E+00	.84619
1.99	3.24063E-02	4.43595E-02	.83779	5.1583	1.2399	1.0000	0.00000E+00	.83779
2.21	2.78924E-02	3.81806E-02	.83062	5.1583	1.2399	1.0000	0.00000E+00	.83062
2.44	2.40072E-02	3.28623E-02	.82450	5.1583	1.2399	1.0000	0.00000E+00	.82450
2.66	2.06632E-02	2.82849E-02	.81927	5.1583	1.2399	1.0000	0.00000E+00	.81927
2.89	1.77850E-02	2.43450E-02	,81480	5.1583	1.2399	1.0000	0.00000E+00	.81480
3.11	1.53077E-02	2.09539E-02	,81096	5.1583	1.2399	1.0000	0.00000E+00	.81096
3 34	1.31754E-02	1.80352E-02	.80768	5.1583	1.2399	1.0000	0.00000E+00	.80768
3.56	1.13402E-02	1.55231E-02	.80486	5.1583	1.2399	1.0000	0.00000E+00	.80486
3.79	9.76060E-03	1.33608E-02	.80245	5.1583	1.2399	1.0000	0.00000E+00	.80245
4.01	8.40103E-03	1.14998E-02	,80037	5.1583	1.2399	1.0000	0.00000E+00	.80037
42	7.23083E-03	9.89795E-03	.79859	5.1583	1.2399	1.0000	0.00000E+00	.79859
4.46	6.223ME-03	8.51924E-03	.79706	5.1583	1.2399	1.0000	0.00000E+00	.79706
4.50	6.07402E-03	8.31444E-03	.79682	5.1583	1.2399	1.0000	0.00000E+00	.79682

VOL EXT. COEF = 4.6899E-03

VOL ABS COEF = 4.6614E-03

MASS CONC = 7.3264E-02

MASS CL = 7.3264E-02

BASS OPTICAL DEPTH = 1.0050E-02

NORM.D RANGE = .1917

** END OF CASE 3 **

END EOSLEL RUN

STOP 000

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CLIMAT	(vol 8)	Climatology
CLTRAN	(vol 9)	Transmission through Clouds
COMBIC	(vol 11)	Obscuration Model for Mutiple Battlefieltl-Induced Contaminants
COPTER	(vol 10)	Obscuration due to Helicopter-Lofted Snow and Dust
FASCAT	(vol 22)	Fast Algorithm for Atmospheric Scattering Calculations
FCLOUD	(vol 18)	Transmission through Cloud of Ellipsoidal Geometry
OVRCST	(vol 18)	Path Radiance/ Contrast Beneath Overcast Conditions
FITTE	(vol 15)	Fire-Induced Transmission and Turbulence Effects
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